

2011

Air emissions: the effects on the shipping industry and ports : implications for the Port of Singapore

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WORLD MARITIME UNIVERSITY

Malmö, Sweden

**AIR EMISSIONS:
THE EFFECTS ON THE SHIPPING INDUSTRY AND
PORTS**

Implications for the Port of Singapore

By

JOLYN TAY LING LING

Singapore

A dissertation submitted to the World Maritime University in partial
Fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

In

MARITIME AFFAIRS

(Maritime Law and Policy)

2011

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

A handwritten signature in blue ink, consisting of a large, stylized 'D' with a vertical line through it, followed by a horizontal line.

Signature:

Date: 24 October 2011

Supervised by: Dr. Raphaël Baumler

World Maritime University

Assessor:

Institution/ organization:

ACKNOWLEDGEMENTS

I would like to thank my supervisor Dr. Raphaël Baumler for his advises and guidance during the work of this dissertation.

I would also like to thank:

Stephanie and Simon from Zodiac Maritime Agencies Ltd. for their time and opinions provided during the interview for this dissertation.

Ministry of Land, Transportation and Maritime Affairs of Korea, Port Authority of Shanghai, and Maritime and Port Authority of Singapore for agreeing in providing information and opinions through questionnaire.

Mr. An Kwang and Mr. Zhang Huixia for assisting in linking up with the Korea and Shanghai authority respectively.

My superior and colleagues from Maritime and Port Authority of Singapore in assisting and providing the necessary information and statistics required for the work of this dissertation.

Last but not least, to my dearest family for their morale support.

ABSTRACTS

Title of Dissertation: **Air Emissions: The Effects on the Shipping Industry and Ports – Implications for the Port of Singapore**

Degree: **MSc**

‘Climate change’ has been regarded as one of the major problems of the atmosphere. The international shipping attributes to approximately 3 percent of the global emissions. Studies had showed that the ship emissions have certain level of impact to the cause of climate change, and the air quality which directly or indirectly affects human health.

MARPOL Annex VI was the first effort made by the International Maritime Organization (IMO) to curb the emissions from ships. It places a global cap on sulphur content of fuel oil and introduces technical code to marine engines in phases to reduce the emissions of nitrogen oxide (NO_x). IMO through the Marine and Environment Protection Committee (MEPC) has also adopted a package of measures to mitigate and reduce ship emissions through controlling the efficiency of ships’ operation and ships design, i.e. EEDI and SEEMP. The EEOI and Market-based Mechanisms (MBMs) are also on the study table of IMO. If the MBMs are introduce it will inevitably influence the business strategy and policies of the shipping companies, operators and other related shipping industry.

Due to the establishment of the various emission control policies, abatement technologies and alternative fuels have been explored at different industries and level hoping to find the best technology or solution for the ships to comply with the regulations.

Aligned with the international ships emissions policies, Singapore has taken a 3-pronged approach to cover its duty as a flag administration, a major port, and as a maritime hub

promoter to encourage development of local innovation for new technology for reduction of GHG emission.

This dissertation will look at some of the strategies and policies adopted in major ports, and the challenges faced by the shipping companies in meeting with the international, regional and national ship emissions requirements. It will also examine the strategy and approach by Port of Singapore and makes possible recommendations to improve the emission reduction policy framework.

The conclusion of this dissertation will discuss the impact of the air emission policies have on the maritime industry and examine the gaps in the current 'green' policies from port of Singapore. A list of recommendations was proposed for the port of Singapore to mend these gaps.

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List of Abbreviations

CDP - Carbon Disclosure Project

CO₂ – Carbon Dioxide

COP17 – The 17th Conference of the Parties to the United Nations Framework Convention on Climate Change

EEA - European Environment Agency

ECAs – Emission Control Areas

EU – European Union

EEDI – Energy Efficiency Design Index

EEOI - Energy Efficiency Operational Indicator

ETS - emission trading schemes

EGR – Exhaust Gas Recirculation

ESI – Environmental Ship Index

GHG – Greenhouse Gas

HFO – Heavy Fuel Oil

IAPH - International Association of Ports and Harbors

ICAO – International Civil Aviation Organization

IMO – International Maritime Organization

IPCC – Intergovernmental Panel on Climate Change

LDCs - Least Developed Countries

LNG - Liquefied Natural Gas

MARPOL - International Convention for the Prevention of Pollution from ships

MEPC - Marine Environment Protection Committee

MDO – Marine Diesel Oil

MBMs - Market-based Mechanisms

MGO – Marine Gas Oil

NO_x – Nitrogen Oxide

NO – Nitric Oxide

NO₂ – Nitrogen Dioxide

O₃ – Ozone

PM - Particulate Matters

RO – Recognized Organization

SEEMP – Ship Energy Efficiency Management Plan

SIDs - Small Island Developing States

SMRs - Small Modular Reactors

SECAs – Sulphur Emission Control Areas

SO_x – Sulphur Oxide

TSPP - International Conference on Tanker Safety and Pollution Prevention

UNEP – United Nations Environment Program

UNFCCC – United Nations Framework Convention on Climate Change

VOC - Volatile organic compounds

VLCC – Very Large Crude Carrier

WPCI - World Ports Climate Initiative

1. INTRODUCTION

1.1 Background on the push for Air Emission Control in Maritime/ Shipping Industry.

‘Climate change’ has been regarded as one of the major problems posed to the atmosphere, socio-economic, safety and etc. The UN Secretary General had commented,

“that climate change is the major, overriding environmental issue of our time, and the single greatest challenge facing environmental regulators. It is a growing crisis with economic, health and safety, food production, security, and other dimensions.”¹

In the United Nations Framework Convention on Climate Change (UNFCCC), *climate change* defined as:

“a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”

In accordance with UNFCCC, the average temperature of the earth’s surface has risen by 0.74 degrees Celsius since the late 1800s, and it is expected to increase by another 1.8 to 4 degrees Celsius by the year 2100. The main reason behind these changes is the long-term impact of industrialization, namely burning of oil, gasoline, and coal, deforestation, and practice of certain farming methods.

¹ Source: <http://www.unep.org/climatechange/Introduction/tabid/233/Default.aspx>

² Art. 1(a), Convention on Long-Range Transboundary Air Pollution (Geneva, November 13, 1979)

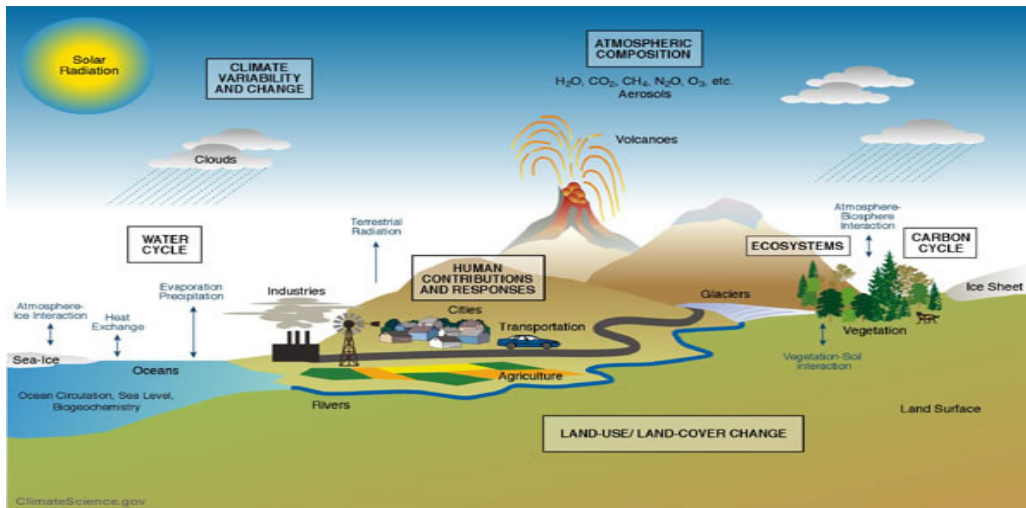
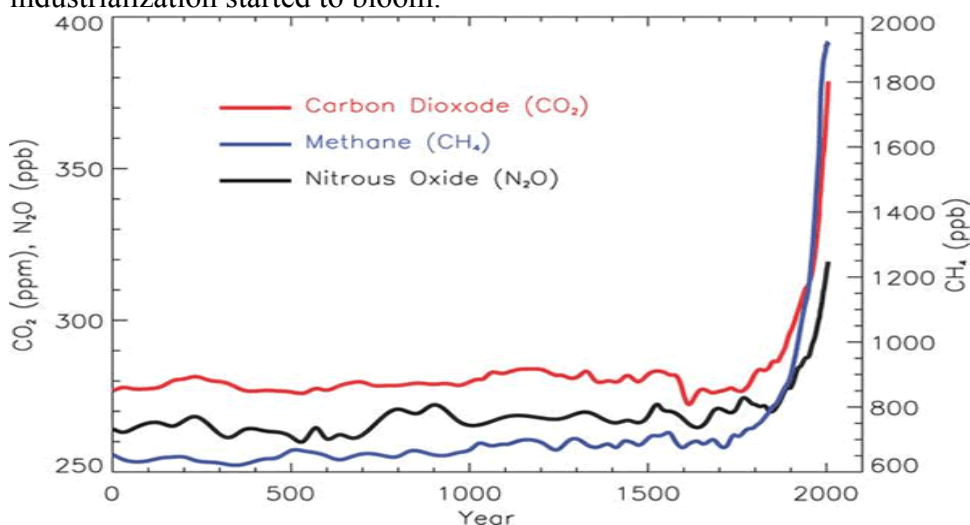


Figure 1 - Types of human activities that contributes and responses to climate change.

Source: www.geology.com

Over the last 50 to 100 years, increasing industrialization of human activity has started to affect the climate balance. The following table shows the increasing trend on the atmospheric concentration of some GHG due to the bloom in industrialization since 1750.

Table 1 - Concentration of greenhouse gases from 0 to 2005. This graph shows the atmospheric concentration, where increased has been observed since 1750 when industrialization started to bloom.



Source: www.ipcc.ch/

Through the generalization of industrialization of human activities the effect of air pollution is no longer localized. As the industrialization process had increased the height of the factory chimney as a solution to reduce the air pollution concentration impact locally, the emission was taken to higher atmospheric levels causing long-range pollution damage.

The first mention of air emissions was at a regional forum where a 'Declaration on Air Pollution Control' was adopted by the Council of Europe in May 1968. Subsequently, the 1972 United Nations Conference on the Human Environment in Stockholm started the international cooperation to combat acid rain. In 1979, a ministerial meeting was held on the protection of the environment creating the Geneva Convention on Long-range Transboundary Air Pollution to which 34 governments and the European Community were signatories. Successive, protocols to this Convention were later adopted on reducing sulphur emission in 1985; controlling emissions of nitrogen oxides in 1988; controlling of volatile organic compounds in 1991; and in 1994 a further reduction in sulphur reduction.

Air emission can be categorised into 2 main areas, namely: air pollutants that is caused by the release of Sulphur oxide, Nitrogen Oxide, ozone depleting substances, volatile organic compounds, incineration and etc; and greenhouse gases (GHG) that is mainly cause by the release of CO₂ and caused global warming.

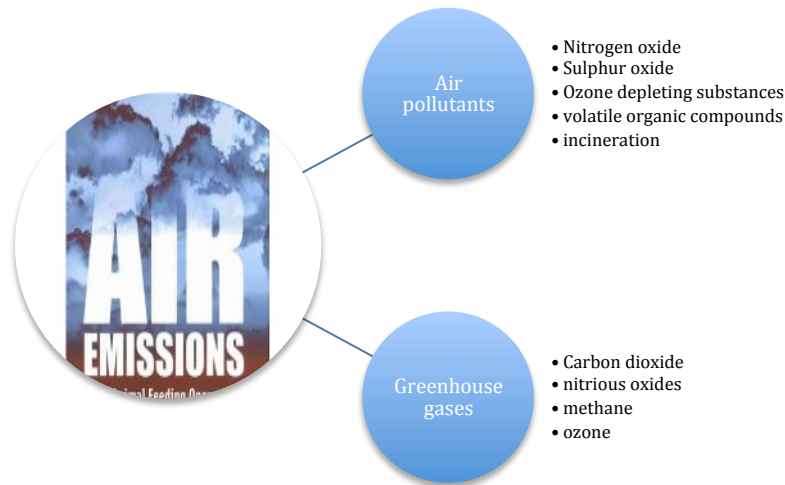


Figure 2 - Types of air emissions.

Source: Unpublished, master's dissertation, Malmo, World Maritime University.

The effect of the greenhouse gases is trapping of the infrared radiation release within the Earth itself and causing it to be warmer. The following diagram describes the effects of greenhouse gases when it traps infrared radiation within the Earth.

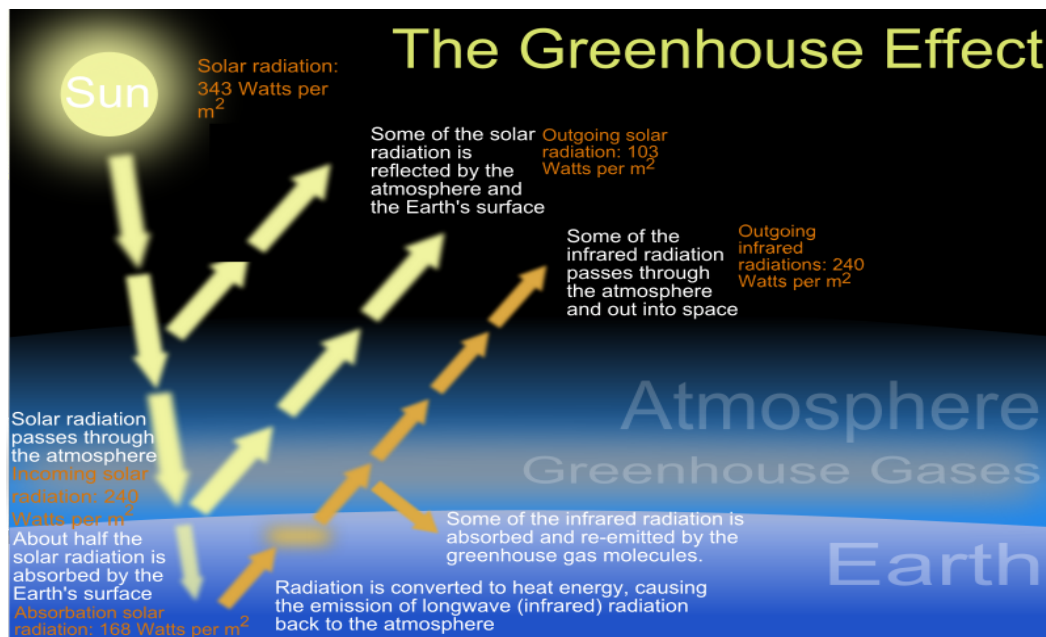


Figure 3 - Effects of greenhouse gases on the atmosphere.

Source: http://en.wikipedia.org/wiki/Greenhouse_gas

The other component of air emission is air pollution. Air pollution is defined as,

*The introduction by man, directly or indirectly, of substances or energy into the air, resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property, and impair or interfere with amenities and other legitimate uses of the environment.*²

This definition acclimates the notion of pollution focusing on the harm or risk resulting from changes in the environment. Air pollutants present effects on human health and the environment. The list of health and environmental effects resulted from the air pollutants are illustrated in Appendix 1.

This dissertation will examine the chain of developments leading to air pollutants and greenhouse gas emission control from ships; how shipping contributed to the world emission figures, the reduction methodology used and efforts expanded so far. It will also critique the effectiveness of the measures and policies adopted so far.

Air emission from Shipping Industry

We can identify air emissions into: air emission from marine engine, cargo related emissions, and equipment related emissions. However, for the purpose of this dissertation I will focus only air emissions from ships related to exhaust emissions. With regards to emissions from ships, it generally separates into two categories, those that directly affect global warming, i.e. cause the climate change; and those that affects air quality, i.e. direct or indirectly affect human health.

² Art. 1(a), Convention on Long-Range Transboundary Air Pollution (Geneva, November 13, 1979)

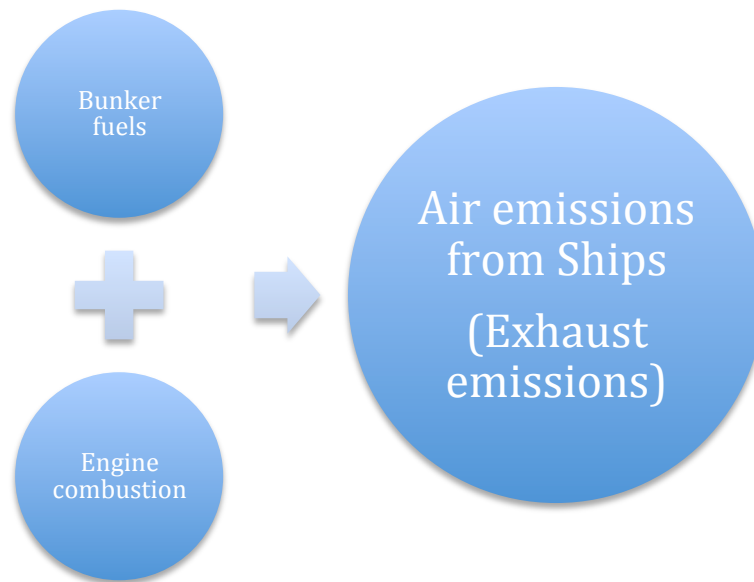


Figure 4 - Types of emissions generated by ships.

Source: Unpublished, master's dissertation, Malmo, World Maritime University.

- The Sulphuric gas originating from industrialization, in part converts into sulphate in the troposphere and lower stratosphere and becomes sulphuric acid which is also known as sulphur oxide (SO_x). It then converts into rain where it impacts on fresh water and the soil, which then directly impact on the roots of trees, as *acid rain*. The major sources of sulphuric gases are from fossils such as coal and oil combustion. In the 19th century, the *Trail Smelter* case was the first major arbitration decision in international jurisprudence which defined the obligation of each state not to cause or allow to be caused transfrontier pollution damage to other states. By the 1970s, non-industrial countries and agricultural areas were affected by the emissions. The Scandinavian countries especially felt the effects. A survey of European forests in 29 countries was carried out in 1995-1997³. The report found that one in every four trees are suffering from abnormal thinning of the crown, and one of the primary factors cited was atmospheric pollution.

³ Forest Conditions in Europe, Results of the 1996 Crown Conditions survey: 1997 Technical Report, by UN Economic Commission for Europe and European Union

- Nitrogen Oxide (NO_x) is a mixture of oxygen and nitrogen. NO_x is a generic term for nitric oxide (NO) and nitrogen dioxide (NO₂) in terms of air pollution regime. They are produced during the process of high temperature combustion in motor engines. This produces an endothermic reaction and produces various oxides of nitrogen. NO_x may react with water and form nitric acid, and when dissolved in atmospheric humidity, may cause *acid rain*. Nitrogen Oxide (NO_x) together with sulphur oxide and carbon dioxide creates ozone (O₃). The O₃ at ground level is harmful to people who are vulnerable to respiratory disorders, especially children, the elderly and the sick. The major contributors to ozone depletion are industries using fossil fuels such as power stations, motor vehicles etc.
- Ozone is a form of oxygen, consisting of three atoms, whereas the oxygen breathed in the atmosphere consists of two atoms. When the ozone is at the ground level, it presents in the form of “smog” and produces harmful effects to plants, stratospheric ozone⁴.
- Volatile organic compounds (VOC) are organic chemicals that have a high vapour pressure at room-temperature condition. It is a result of the process in low boiling point, and causes large amount of molecules to evaporate from the liquid or solid form and enter in surrounding air. VOC has long-term health effects because generally the concentration is low and the symptoms will take longer time to develop.
- Carbon dioxide (CO₂) is a by-product of the combustion of fossil and other natural fuels such as wood, coal, oil and gasoline. The buildup of gases such as carbon dioxide, nitrogen oxide, methane and ozone, which are commonly known

⁴ Stratospheric ozone is a layer that filters a part of the sun's ultraviolet radiation. The reduction of this layer will cause an increase in human skin cancers and harm to the eyes and unforeseen biological effects.

as the greenhouse gases, is believed to be the reason behind the global warming. International concern over climate change came to the forefront through a series of international conferences on CO₂ between 1985 and 1987⁵.

The burning of low quality bunker fuel, and the diesel engines combustion are the main cause for the air emissions from the shipping industry. As both of these are emitted as exhaust from the ships, it is also commonly known as exhaust emissions.

Causes of such air pollution from the shipping industry

The main cause of SO_x in terms of shipping emissions is from bunker fuels. The sulphur content level of crude oil varies from 0.1 to 4 percent. The refinery process accentuates this and the sulphur remains in the residual fuel, ie. Heavy Fuel Oil (HFO). Unlike SO_x, the emission of NO_x is not entirely related to fuel quality. It mainly originates from two sources: oxidation of nitrogen from the combustion of air at a high temperature and oxidation of nitrogen compounds in fuel itself. The following formula listed the elements involved in the process of combustion within a marine diesel engine and its resultants.

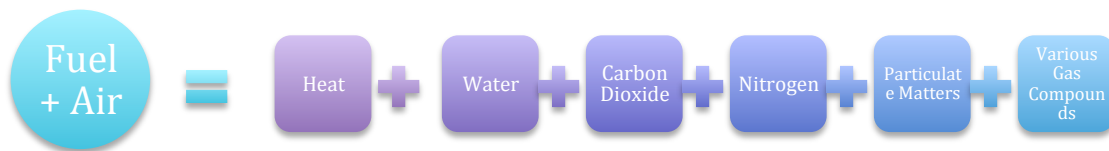


Figure 5 - Elements produced during combustion process

Source: Dr. Raphaël Baumler, World Maritime University.

1.2 Scope

This dissertation will summarize some of the strategies and policies adopted in major ports, together with the feedbacks received through interviews with major shipping

⁵ Villach Conference 1985, Brussels Symposium 1986, Bellagio and Villach Seminars 1987.

companies, the dissertation will conclude with recommendations on strategy and policy on reduction of air pollutants and greenhouse gas emissions (ie. NO_x, SO_x and CO₂) for the Port of Singapore. The research will focus on NO_x, SO_x and CO₂ emissions which are currently regulated or will be regulated under MARPOL Annex VI. These are the main elements produce directly or indirectly via marine engine emissions or due to the bunker fuel used by ships.

1.3 Methodology

The methodological approach to this research is primarily qualitative,

- Covers analysis and document review of new technology and designs for new and existing ships to reduce the carbon footprint for new and existing ships;
- Market trends on the development of air emission control measures; on the push for air emission control for the shipping industry;
- Impact of political and regulation influences at international, regional and national levels;
- Analysis of the existing practices and strategies adopted by various ports; and
- Interviews carried out with two major shipping companies (Zodiac and Company “X” - *preferred not to be named*) and questionnaire with several ports authorities in Asia region (China, Korea and Singapore).

This dissertation will also look at the quantitative assessment of,

- The current ship operating cost (ie. burning heavy fuel oil (HFO) and without having to change to low-sulphur fuel) and the operating costs for burning of cleaner or low-sulphur fuel; and
- Analysis will be made on the long-term impact on ship operating costs for burning of cleaner or low-sulphur fuel.

2. POLITICAL LAYERS IN POLICY MAKING

Over the years efforts have been made to remedy local forms of pollution such as smoke, noise and water pollution. As soon as pollution became a global concern the first genuine measures for environmental protection only surfaced during the later half of the 20th century. The policies implemented thus far can be divided into three main layers, namely, at international level, regional level and national level. This chapter will discuss the political layers in policy making relating to control of air emissions. The following hierarchy chart shows the relationships of the organizations, conferences and convention developed to govern the air pollution issues at different levels.

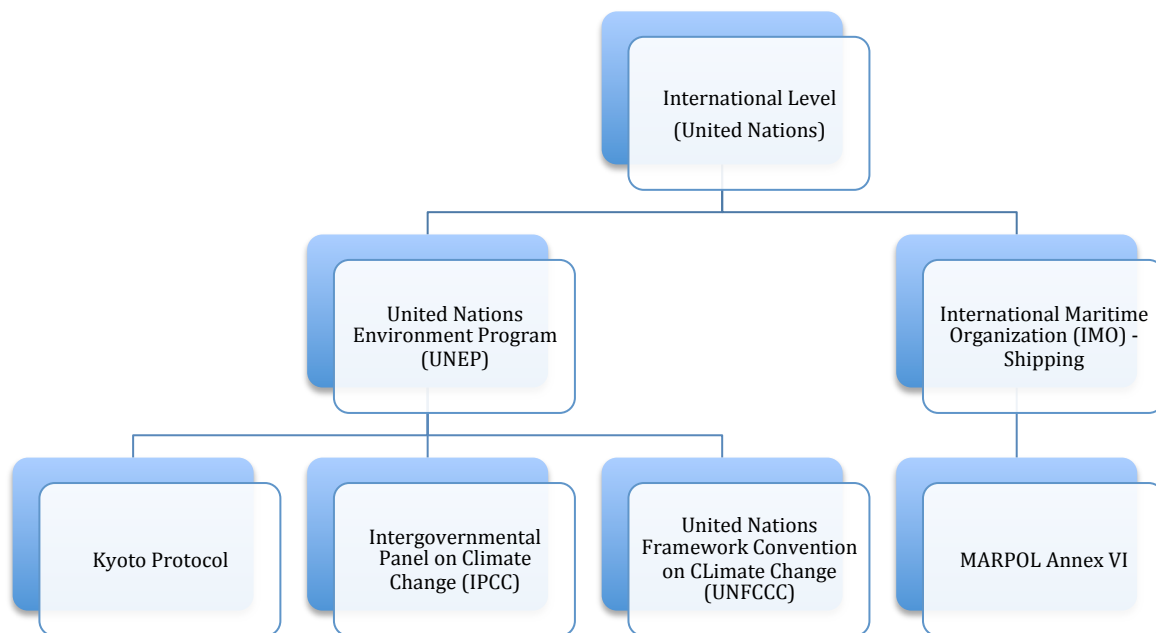


Figure 6 - International bodies and conventions relating to air emissions control.

Source: Unpublished, master's dissertation, Malmo, World Maritime University.

2.1 International Level

At international level, the United Nations (UN) is the main governing body for air emissions related issues. It formulates strategic policies and principles in the areas of human rights, labour, environment and etc. In the area of environment, it also acts as the international body to create measures and regulations to mitigation climate change impact via draft legislations that are to be implemented by the member states. The following figure illustrates the milestone of the international organizations and conferences developed in relation to climate change issues.

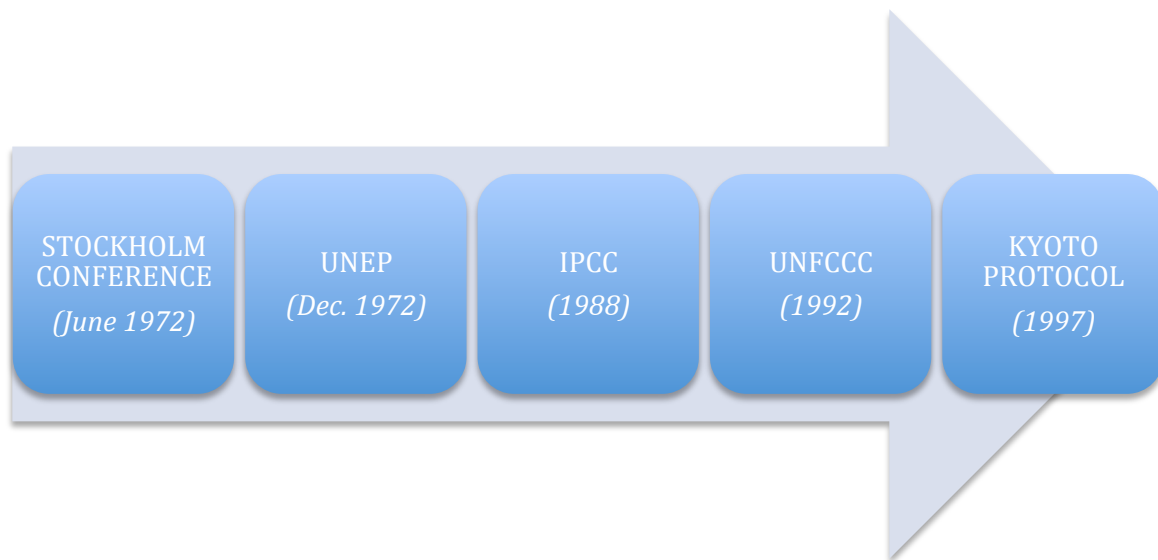


Figure 7 - Development of International Conference and Organization relating to reduction of air emissions.

Source: Unpublished master's dissertation, World Maritime University, Malmo, Sweden.

- The Stockholm Conference took place from 5 to 16 June 1972. It was initiated by the UN as a support to the 1968 actions in protecting the environment. The decision from the conference has raised the mandated of environmental problems at the inter-governmental level, and has global influence in the environment conception, policies. It contains a total of twenty-six principles covering issues

relating to preservation and enhancement of the human environment. Through the Stockholm Conference, the decision for the set up of the UNEP was crystalized.

- The United Nations Environment Program (UNEP) was created as a special subsidiary organ after the Stockholm Conference. UNEP acts as the central organ of action and coordination for environmental matters within the United Nations system as well as for regional organizations outside the United Nations. It also acts as a promoter for action by other institutions and studies environmental challenges and intricate program. However, the maritime industry has always being excluded from the agenda of the UNEP meetings, as there is an existing international organization, i.e. International Maritime Organization (IMO) that regulates the maritime industry.
- The Intergovernmental Panel on Climate Change (IPCC) is a scientific body created by World Meteorological Organization (WMO) and UNEP to provide the governments on the scientific view of climate change and its socio-economic impact. The role of IPCC today has been expanded to also include the options of adaption of the impacts and mitigating measures relevant to climate change caused by human activities.
- In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted as the first international convention and was actively accepted by countries with the objective of stablising greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human interference with climate system.
- Since human activities were viewed as the core reason for causing global warming, the Kyoto Protocol was developed to fight this phenomenon. The Kyoto

Protocol is a protocol under the United Nations Framework Convention on Climate Change (UNFCCC). It was adopted in 11 December 1997 at Kyoto, Japan, and came into force on 16 February 2005. The protocol contains provisions for reducing gas emissions from shipping which treat it with a different approach. These include different approaches for domestic and international shipping. As of 2010, 191 countries had signed and ratified the protocol. Domestic shipping emission is included within the target of the developed countries (ie. Annex I) which had committed themselves to a reduction of four GHG (ie. CO₂, methane, NO_x, SO_x) by 5.2 percent for 2008-2012 as compared with the 1990 level.

Kyoto Protocol, Article 2.2 defines emission from international shipping:

“Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively”.

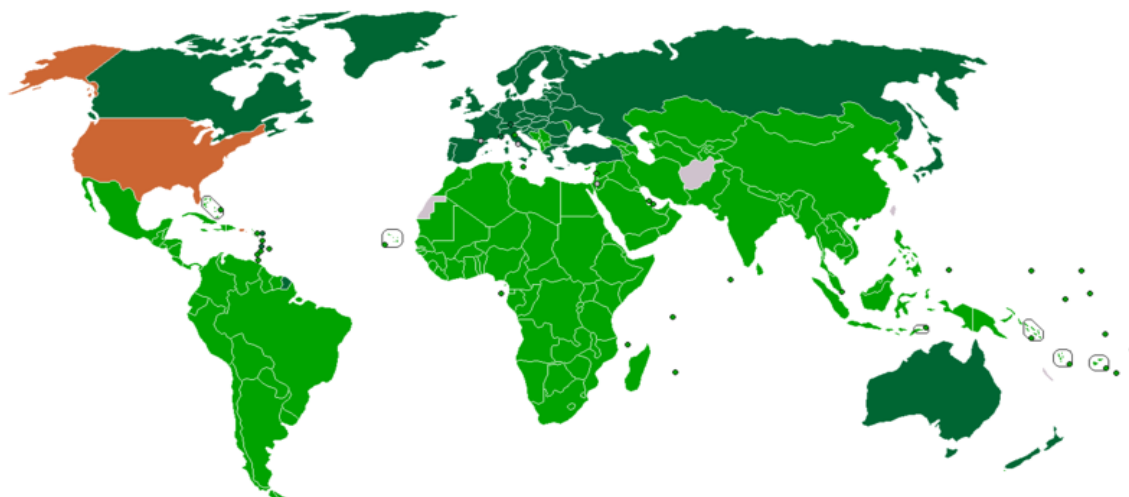


Figure 8 - Kyoto protocol participation map. Green- countries which had ratified; dark green are Annex I and II countries that have ratified the treaty; and brown are countries which do not intend to ratify.

Source: http://unfccc.int/kyoto_protocol/items/2830.php

2.1.1 Influence of Kyoto principles on shipping

Prior to the adoption of the Kyoto Protocol, in September 1997, through the conference of the International Convention for the Prevention of Pollution from ships (MARPOL), it was decided that the IMO's Marine Environment Protection Committee (MEPC) should do a feasibility study on reduction of GHG emissions from shipping. The report of the study was presented in September 2000 at MEPC 45. The study concluded that shipping accounted for 1.8 percent of the world's total anthropogenic CO₂ emissions, which was higher than the countries which had undertaken to reduce their emission levels under the Kyoto protocol. However, as compared with airfreight, it was acknowledged that shipping is the most efficient means of freight transportation with an energy intensity two orders of magnitude lower than airfreight. The study also noted that 16 percent of the cargo shipped in bulk carriers began and ended in non-Annex I countries, this which pointed to the fact derived that international shipping should be considered as a developed affair. The report then concluded that the possibilities for reducing shipping emissions through operational measures were 'significant', while technical implementation through international standards will be easier for new ships rather than retrofitting of existing ships.

2.1.2 Role and policies of International Maritime Organization (IMO)

IMO is part of the UN organization that is looking after the maritime sector. It is established as a permanent international body to promote maritime safety. The purposes of IMO as summarized by Article 1(s) of the IMO Convention,

“to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning

maritime safety, efficiency of navigation and prevention and control of marine pollution from ships”

Hence, the IMO is only empowered with administrative power related to these purposes. The member states are the ones that will be required to implement the conventions adopted in their national legislation in order for it to be enforceable within their country.

Due to the increasing volume in sea transportation of oil and liquid substances in bulk during the 1970s, the International Convention for Prevention of Pollution from Ships, 1973 was created to preserve the marine environment by eliminating pollution by oil and other harmful substance, and minimizing accidental discharge of such substances from ships. However, it did not come into force till 2 October 1983 when the 1978 Protocol was adopted in the International Conference on Tanker Safety and Pollution Prevention (TSPP Conference) held from 6 to 17 February 1978. The Convention as modified by the 1978 Protocol is then known as the “International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto”, in short, “MARPOL 73/78”.

“The International Convention for the Prevention of Pollutions from Ships, 1972, as modified by the Protocol 1978 (MARPOL 73/78) comprises of Regulations covering the various sources of ship-generated pollution contained in the five Annexes of the Convention. The Convention has also bee modified by the Protocol of 1997, whereby a sixth Annex was adopted”⁶

MARPOL consists of six annexes concerning different forms of marine pollutions from ships. To date, 98% of the world’s shipping tonnage is party to the Convention. A State

⁶ MARPOL 73/78 - Introduction

that becomes a party to MARPOL must accept Annex I and II, where Annex III to VI is optional.

The issues of air pollution were first discussed at IMO MEPC at the mid-1980s, where the quality of fuel oils in relation to discharge requirements in MARPOL Annex I. In 1988, following the submission from Norway highlighting the seriousness of air pollution from ships, and the declaration made in the Second International Conference on the Protection of the North Sea in November 1987, the North Sea states had agreed to initiate actions within appropriate organizations such as IMO to reduce the atmospheric pollution by improving the quality of heavy fuel oil. MEPC agreed to include the issue of air pollution in its work plan. By 1989, it was agreed at MEPC to insert it as a part of its long-term work plan commencing March 1990, and to look at the prevention of air pollution from ships and fuel oil quality.

In 1997, recalling the principle 15 of the Rio Declaration in Environment and Development for implementing of precautionary measures for reducing of air emissions, IMO adopted a set of regulations reside under a new Annex, ie. Annex VI to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocols of 1978 and 1997 thereto (MARPOL) which entered into force on 19 May 2005.

2.2 Regional Level

At regional level, currently there are only two main regional policies that control the emissions from ships when it is entering these areas.

- One is the EU directive 2005/33/EC which is set for reduction of SO_x emission within the EU member states.

- The other is the Sulphur Emission Control Areas (SECAs), or currently known as the Emission Control Areas (ECAs) which is imposed through MARPOL Annex VI Regulation 13 and 14. SECAs and ECAs will be further discussed in chapter 3.

2.2.1 An illustration of European Union (EU) on air emissions monitoring

In a recent report published by the European Environment Agency (EEA) in tracking of progress towards Kyoto targets and 2020 targets in Europe, 2010, stated that EU-27 has come closely to achieving its GHG emission target of 20 percent from baseline of 1990. Based on the report, in 2009, EU-27 GHG emission level stood at 17.3 percent as compared to 1990. The current EU progress chart is appended in Appendix 2.

2.2.2 Principle of SOx Emission Control Areas and Emission Control Areas

SOx Emission Control Areas (SECAs) was first established in 19 May 2005 and became enforceable on 19 May 2006 in Baltic Sea, and subsequently in North Sea and English Channel in 2007. The purpose of designating SECAs is to establish more stringent controls on SOx emissions from ships. Unlike SECAs, Emission Control Areas (ECA) covers a wider scope of air emissions control from ships. Ships entering or operating within ECAs will be required to comply with emissions control of SOx, NOx and Particulate Matters (PM). North America is one of the first areas designated by IMO as ECA, and it will be in force in 2012.

Establishment of SECAs and ECAs have pros and cons to the region. Unlike the western region, most of the Asia countries have approaches the issues of air emission control through voluntary basis. One of the possible reasons is due to the close proximity of the countries and gaps in the local shipping standards when in comparison with the international standards makes it tough to implement a single requirement on emission control measures. Economical reasons may be another supporting reason on the “careful” approach the Asia countries are taking. Bunkering and shipping is one of the economic

contributors, if harsh emission control regulations are imposed without careful evaluation of the market impact, as it will affect not only the shipping industry in terms of trade volume, but also the elements of employment in the region.

2.3 National Level

At national level, ship emissions policies can be implemented in three different angles. One is from the role of the flag administration. The flag state is required to impose regulations that had been introduced internationally on its flagged ships to ensure compliance. Second, is the role of a port state: if the state has ratified the MARPOL Annex VI, then it will be required to ensure that ships entering their port have to comply with the MARPOL regulations. This is normally carried out through Port State Control inspection. Third, is the role as coastal state: as it may choose to impose stricter requirements on ships entering waters under their jurisdiction. The common reasons given for such, is for improvement of public health and protection of environment.

Social and political reasons are part of the main reasons for some nations to impose stricter air emission regulations than others. Other considerations that may hold back strict implementation of air emission control regulations may be the impact of such implementation on the country's economy.

2.4 Conclusion

The following figure summarises the different political layers relating to air emissions policies. At highest level, which is the International level we have UNEP which governs the international issues relating to climate change, and IMO which regulates the international shipping matters relating to safety and environment. At the regional level, we have the EU which governs the member states within the Europe region, and SECAs and ECAs which is impose through IMO to restrict the emissions from ships when operating within such areas. Finally, we have the national level where implementation of

policies adopted by IMO at the member states national legislation level, and the enforcement instrument to ensure that the requirements are been complied with.

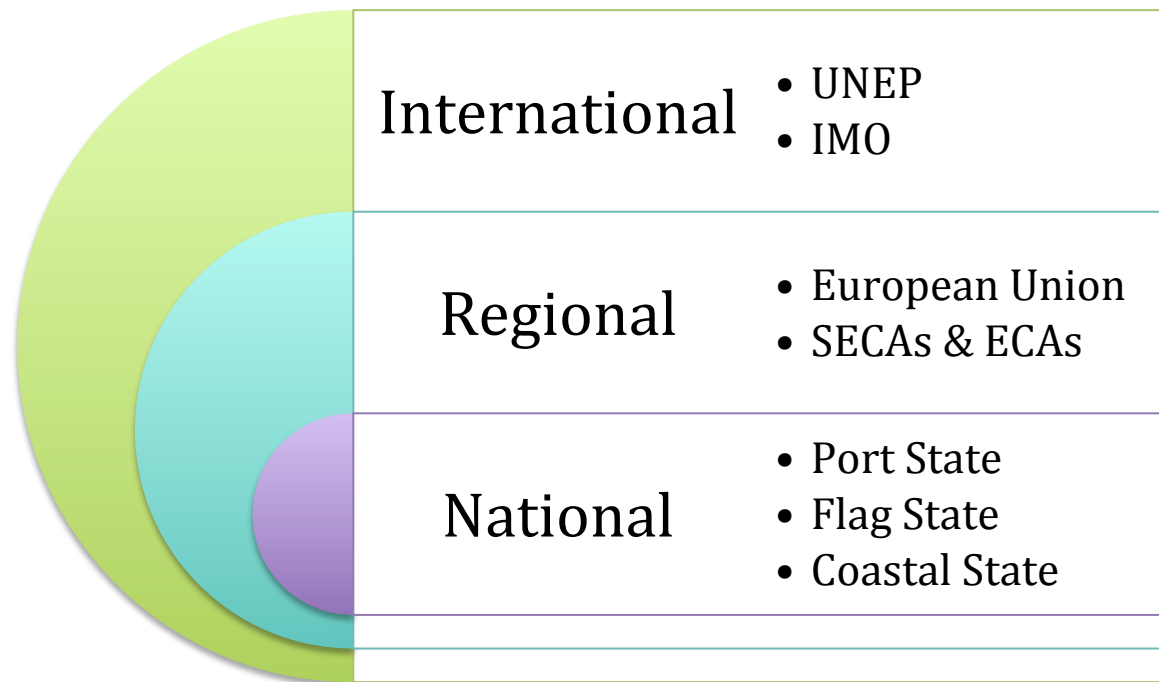


Figure 9 - Political layers in terms of air emissions policies implementation.

Source: Unpublished, master's dissertation, Malmo, World Maritime University.

Now that we have identified the different political layers involved in the air emissions policies making, we will now describe the international instruments developed by IMO for the maritime industry in terms of mitigating ships' emissions.

3. MARPOL Annex VI

“Annex VI is appended to the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, which was adopted by the International Conference of Parties to MARPOL 73/78 in September 1997.”⁷

The Annex VI came into force in 19 May 2005, where more than fifteen states with combined merchant fleets of more than 50% of the gross tonnage of the world’s merchant shipping ratified it. To-date, 53 countries have ratified MARPOL Annex VI which represents 81.88 percent of the gross tonnage of the world’s merchant shipping fleet⁸.

Many discussions had also taken place in IMO to broaden the scope of MARPOL Annex VI in recent years. The most recent guidelines adopted in the 62nd MEPC session had seen that the shipping industry is ready to make effort to go beyond just mitigating the aftermath effect of the pollution from ships. The new requirements will be looking at controlling of emissions from the very beginning when the ship design is still at the drawing board (for new ships), and controlling of operational efficiency of existing ships.

The following flow chart describes the areas covered under MARPOL Annex VI namely, air pollution, bunker and GHG. Elements shaded in blue and brown are measures already introduced and regulated under MARPOL Annex VI. Those in red, are currently still under evaluation in IMO, which are currently not regulated as yet. As mentioned previously, this dissertation will concentrate on SO_x, NO_x and CO₂ and will not be touching on those elements highlighted in brown.

⁷ MARPOL 73/78 - Introduction

⁸Source: www.imo.org/environment

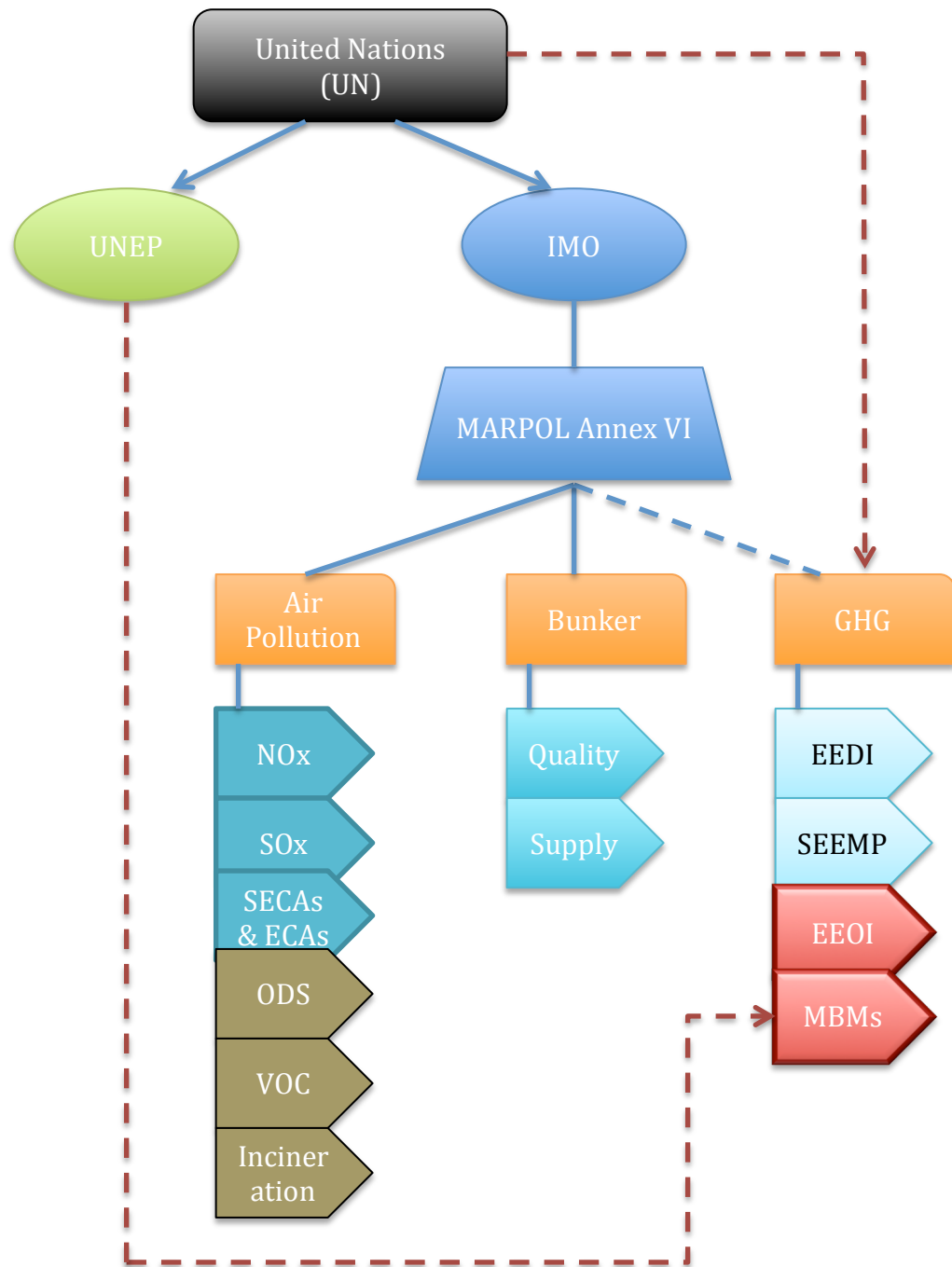


Figure 10 - Regulated items under MARPOL Annex VI

Source: Summarised by author based on information from MARPOL Annex VI, master's dissertation, Malmo, World Maritime University.

3.1 Air Pollution generated by ships

Air pollutants from ships are generally from the ship's engine and fuel used on board. Hence, there are two main areas that are regulated within the Annex VI is air pollution (ie. exhaust emissions) and bunkers. The third area on GHG, requirements have been adopted at the 62nd MEPC and are set to be in-force sometime in 2013. Each of this area will be discussed in this chapter.

MARPOL Annex VI Chapter III, has identified the followings as the main types of air pollution generated from ships:

- Regulation 12 – Emissions from Ozone depleting substances from refrigerating plants and fire fighting equipment.
- Regulation 13 – Nitrogen Oxide (NO_x) emissions from diesel engines.
- Regulations 14 – Sulphur Oxide (SO_x) emissions from ships.
- Regulation 15 – Volatile Organic Compounds emissions from cargo tanks of oil tankers.
- Regulation 16 – Emissions from shipboard incinerators.
- Regulation 18 – Fuel Oil quality.

These regulations are only applicable to ships of 400 gross tons and above and the ship is required to carry an International Air Pollution Prevention Certificate (IAPP Certificate). For ships that are below the tonnage stated, the Administration may establish appropriate measures for compliance with Annex VI.

In addition to the Regulations in Annex VI, there are two MEPC circulars on '*Bunker Delivery Note and Fuel Oil Sampling*' and '*Notification to the Organization on ports or terminal where volatile organic compounds (VOCs) emissions are to be regulated*', which regulated on the bunker qualities and supplies, and VOCs. These two circulars were issued to assist with the implementation of MARPOL Annex VI.

1. MEPC circular on *Bunker Delivery Note and Fuel Oil Sampling*, which is to be implemented in ports of state members to regulate bunker suppliers, and raise awareness in the implementation and enforcement of regulation 18 of Annex VI.
2. MEPC circular on *Notification to the Organization on ports or terminal where volatile organic compounds (VOCs) emissions are to be regulated*. The circular reiterates the importance of Parties giving information on the Organization of ports and terminals under their jurisdiction where such requirements are already in force so that owners and operators are updated on existing and future requirements in order to utilize the systems.

Of these, the impact of NO_x emissions is mainly on local and regional air quality. Although CO₂ has not been identified in MARPOL as type of air pollution generated from ships, the IPCC had estimated that shipping contributes to approximately 1.8 percent of the world CO₂ emissions. Recognizing the impact and contribution of CO₂ from ships, the last MEPC session held from 11 to 17 July 2011, measures to improve ships efficiency in order to reduce the GHG emissions from ships has been adopted, i.e. EEDI and SEEMP. However, measure such as EEOI and MBMs are still on the table for discussions and evaluation by expert group. This dissertation will only address areas relating to NO_x, SO_x and CO₂.

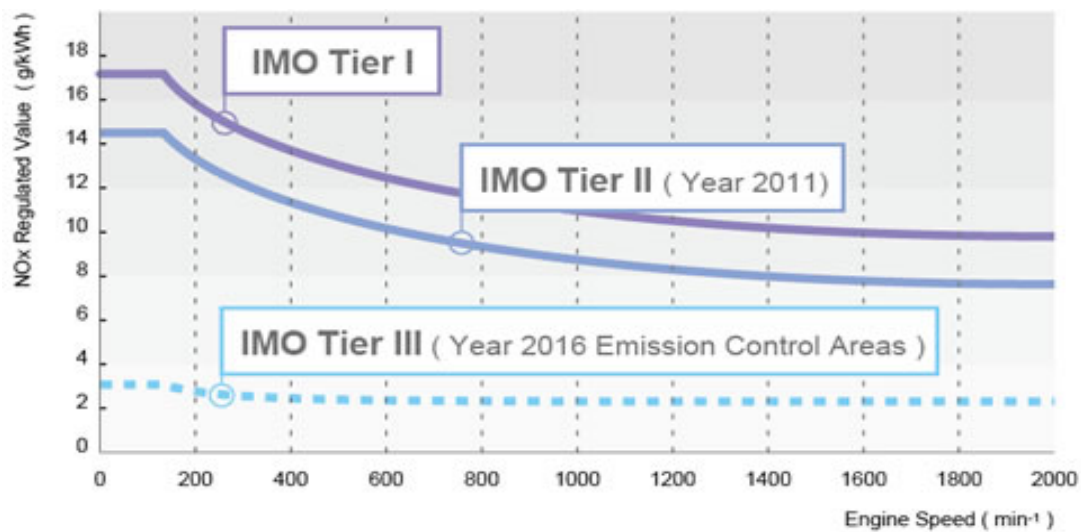
3.1.1 Policies on NO_x emissions control

The seventeenth session of the IMO Assembly took the decision to convene an International Conference of Parties of MARPOL 73/78 from 15 to 26 September 1997. The Conference adopted amendments to the International Convention for the Prevention of Pollution from Ships, 1973, as amended by the Protocol of 1978. A new Annex VI was set up for regulating of Air Pollution from ships. A total of eight

resolutions were also adopted and of which resolution 2 provides the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (NOx Technical Code).

The Technical Code aims at reduction of NOx emissions from marine diesel engines in phases. The initial phase was introduced since year 2000, and the more stringent requirements, Tier II engine has been introduced this year. Tier III engine requirements will only be applicable in ECA from year 2016. The following table describes the timeline for the implementation of the various tiers for marine diesel engine on new ships.

Table 2 - MARPOL Annex VI, NOx emission standards for new ship engines.



Source: Yanmar.

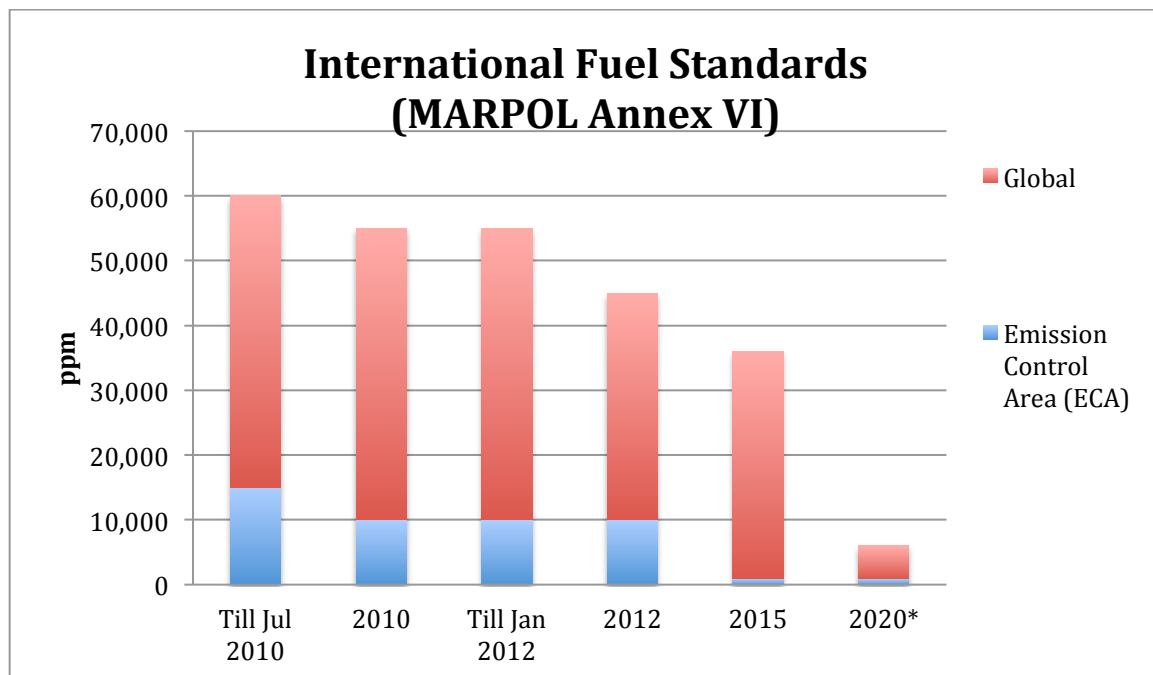
3.1.2 SOx

MARPOL Annex VI, Regulation 14 dictates the requirements of SOx in terms of the fuel oil used on board ships. The current general requirements restrict the sulphur content of fuel oil at 4.5 percent m/m (percentage by mass) and a 1.5 percent m/m cap through implementation of Sulphur Emission Control Areas (SECAs). It also requires the world-

wide residual fuel oils supplies to be in compliance with resolution MEPC.82(43) in terms of sulphur contents.

The 2008 amendments to MARPOL Annex VI covers a progressive reduction in SOx emissions from ships to 3.5 percent from the initial 4.5 percent, which will be implemented in 1 January 2012; and subsequently to 0.5 percent to be implemented in 1 January 2020 globally and 0.1 percent in ECAs. However, this proposal is subjected to a feasibility study for the supply and demand balance on available alternative fuels to be carried out latest by 2018. The requirement for commencing the study is to ensure that the shipping industry will not be left in a lurch, in terms of insufficient low-sulphur fuel supplies to meet the global demand if the global SOx reduction is to be implemented. The following table makes a comparison the fuel standards requirements globally and in ECAs from 2010 to 2020.

Table 3 - Timeline for reduction of SOx in MARPOL Annex VI. **The 2020 fuel standard is subject to the 2018 feasibility study to be conducted.*



Source: Summarized by master's dissertation, World Maritime University, Malmo Sweden, based on MARPOL Annex VI.

3.1.3 SECAs and ECAs

The initial aim of implementing of Sulphur Emissions Control Areas (SECAs) is to reduce sulphur oxide emissions (SO_x) from ships to minimize the acidification of the atmosphere, which results in acid rain.

Under the amendments to Annex VI, the term Sulphur Emission Control Area (SECA) is being replaced by Emission Control Area (ECA) to allow for specifying of limits for Nitrogen Oxide (NO_x), and Particulate Matters (PM), which is known to have harmful effect to human health and sensitive ecosystems. The first SECA, ie. the Baltic Sea came into force in 19 May 2005, and subsequently the North Sea and English Channel in 11 August 2007 followed suit.

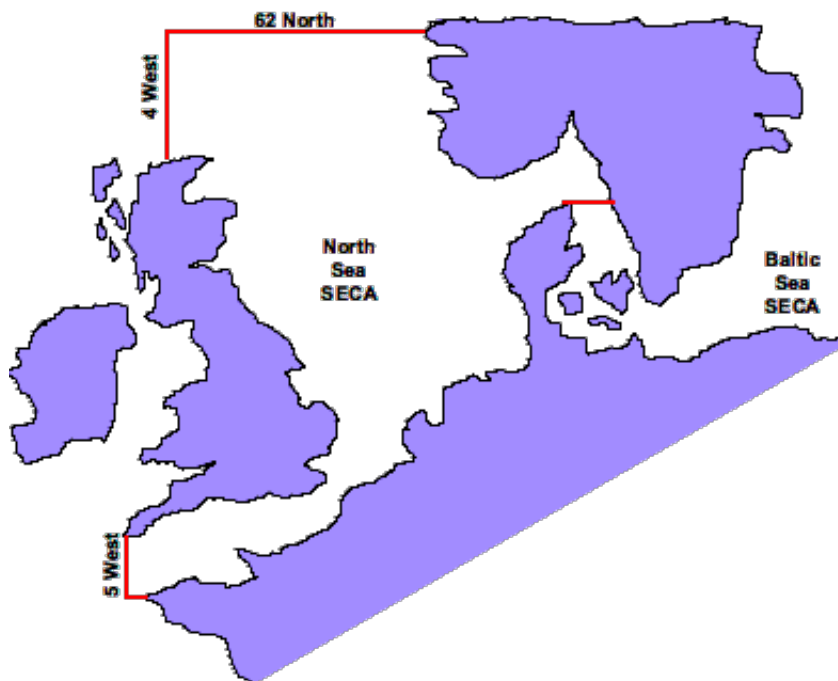


Figure 11 - Sulphur Emission Control Areas (SECAs).

Source: <http://www.severnesnow.com/html/emissions.php>

On 26 March 2010, IMO had adopted East and West Coast of the North America Continent and the Hawaii islands extending up to 200 nautical miles as Emission Control Areas (ECA) that will become enforceable in August 2012. The objective of designating these areas as ECA is to reduce ship-related health impacts in North America which concern public welfare. Some of the related impacts are contribution to the visibility impairment and other detrimental environmental impacts across the whole American continent which has more than 30 major ports.



Figure 12 - Emission Control Areas to be enforced in August 2012, limiting the emission of SO_x, NO_x and PM.

Source: U.S. Environmental Protection Agency. (<http://www.epa.gov/nonroad/marine/ci/420f10015.htm>)

The adoption of SECAs and ECAs can be seen as a benefits going beyond simply monetary. The mitigating measures taken can be considered as external benefits for

public health and improvement of safety which could be considered under the overall benefit and costs gained by the public in the sum of economic benefits for all parties involved.

The limits within the SECAs will also be further reduced to 0.1 percent by 1 January 2015 as compared with current 1.0 percent. The amendment also includes progressive reduction in NO_x emissions from marine engines. Ships constructed on or after 1 January 2016, *ie.* Tier III engines will be required to comply with more stringent control measures under the NO_x Technical Code. The following figure shows the proposed timeline for progressive reduction of ships emissions through imposing of ECAs.

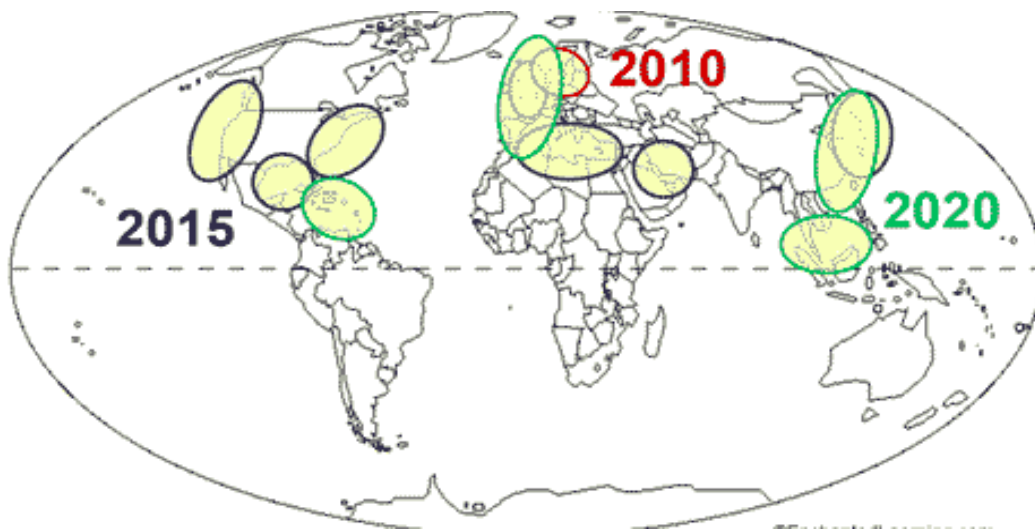


Figure 13 - Overview on the timeline for implementation of ECAs under MARPOL Annex VI.

Source: Ferox.

3.2 Bunker

Fuel oil quality that was previously under the matters between the shipowners and suppliers has now been made statutory in MARPOL Annex VI. Annex VI Regulation 18

specifies the fuel oil quality delivered to and used on board for combustion purposes; limits the SO_x content; contains requirements preventing the existence of potentially harmful substances and chemical waste; mandatory requirement for bunker delivery note and sample of fuel oil delivered; and most importantly it makes the member states to register and declare the local fuel oil suppliers.

3.2.1 Quality: Problems with Low Sulphur Fuel

As mentioned previously, one of the main contributors to the exhaust emissions from ships is via the fuel used on ships. The quality of fuel oil delivered to and used on board ships is currently regulated in MARPOL Annex VI, Regulation 18. In order to meet the quality requirements, burning of Low Sulphur Fuel have been opted has one of the best ways for reduction of emission currently. However, Low Sulphur Fuel does possess certain difficulties. The problems identified are:

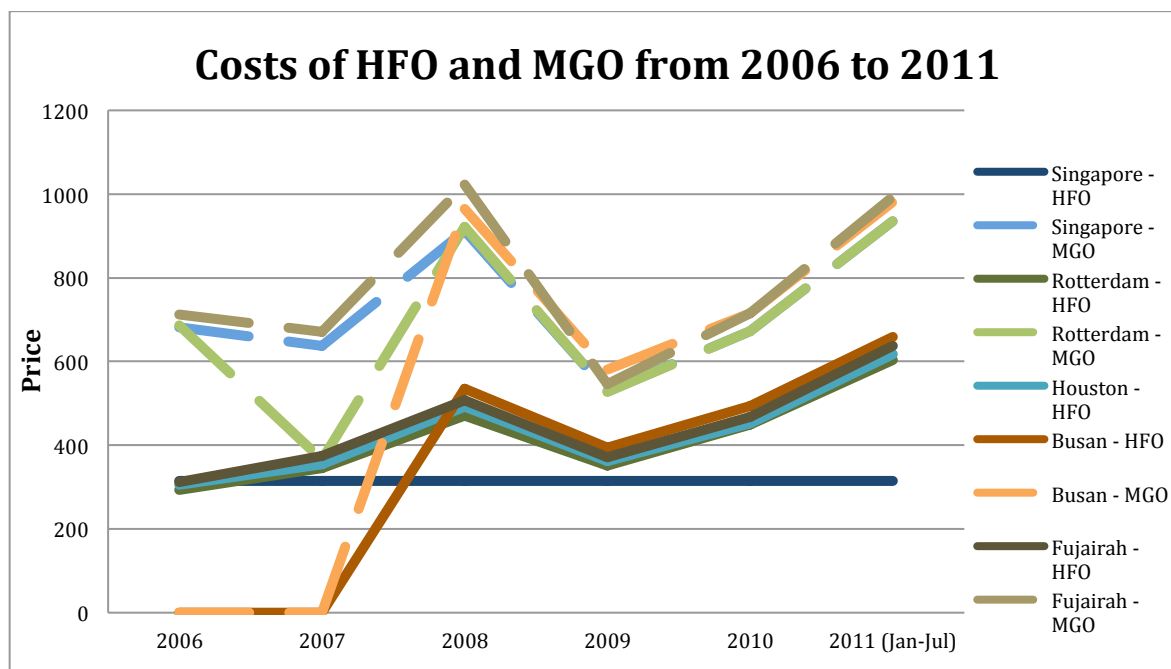
- Ignition and combustion problems due to low sulphur content and increased presence of catalytic fines, abrasives that may damage the engine were identified as some of the issues.
- The readiness and availability of supply of low sulphur fuel was another issue that was raised. Operational problems such as switching over to low sulphur fuel was also identified as another possible issue as any mismatch of timing would cause a violation of the SECA regulations.
- Larger bunker storage tanks required. Generally when distillate fuels are mentioned, it is associated with two types of fuels, namely, marine diesel oil (MDO) which constitute to approximately 1.5 percent of sulphur content; and marine gas oil (MGO) which constitutes approximately 1 percent of sulphur content. Historically it has been proven that ships are able to switch from a higher

sulphur content fuel, ie. HFO to a lower sulphur content sulphur fuel, ie. MDO. Most vessels are required to switch to MDO when maneuvering within port waters of constraint waters, because it provides greater reliability on the propulsion system during critical maneuvering. However, the traditional practices of switching over are only for limited period of time. With the adoption of more and larger ECAs, ships will be required to have sufficient bunker capacity for low-sulphur fuel for transiting the entire ECAs. If the ship were only plying within an ECA then the problem would not be present, as it is purely eliminating the carriage of HFO to low-sulphur fuel. Nevertheless, due to the economical influences in prices of low-sulphur fuel, ship owners and operators will most probably opt to burn two types of fuels onboard, ie. outside of ECA and within ECA. Hence, subjectively this problem would not be present if the global ECA is implemented in 2020. However, for bigger ships that do long-distance trade, it will be required to have two grade segregation tanks with carrying capacity in excess of what is required for the actual voyage.

- High cost. Switching to low-sulphur fuel is one of the most popular options currently is using distillates to replace heavy fuel oil as there are minimal modification required to the ship structure, thence, minimal investment required. Referring to the graph below, it is noticeable that the price of distillate may have been influenced by the implementation of more SECAs, regional and national regulations on restriction of sulphur emissions from ships. The cost of MGO has been rising gradually since the addition of SECAs at North Sea and English Channel in 2007. A drastically drop was observed in 2008 during the economic crisis, but the price has regained its position quickly for the last few years. Based on the historical trend, the price of distillates may increase by 10-20 percent when the latest North America ECA is in-force even before the implementation of bunker levy. The following table shows the costs of distillates in major bunkering

ports around the world from 2006 to 2011. It is noted that other than the period where the shipping industry suffers a crisis, the costs of distillates has been gradually increasing, especially since the implementation of regional policies to reduce ships' emissions such as SECAs.

Table 4 - Development of bunker fuel prices from 2006 to 2011.



Source: Unpublished, summarized by author based on statistics collated by Maritime and Port Authority of Singapore, master's dissertation, World Maritime University, Malmo, Sweden.

3.2.2 Supply

It appears that the easiest and most economical way to comply with emission requirements is the burning of low-sulphur fuel, as compared with investment of high-end technology which is expensive and may not guarantee a return of investment value. This preferred option in the industry generally, is already pre-empted as a problem if the global emission control is to be implemented by 2020. So a scenario of a sky rocketing price for low-sulphur fuel may be created, while on the other hand, the price for HFO may drop tremendously. So, this might be the only reason where a ship owner may

consider the higher investment of technology on their new build. However, the study on supply and demand required from the shipping industry may not pose a sufficient duration for a company to make fast enough decision and investment to ride on this wave. There are currently two methods where low-sulphur fuels can be produced:

1. usage of residues from low-sulphur content crude (commonly known as “sweet” crude)
2. De-sulphurigation and blending of generic crude oils.

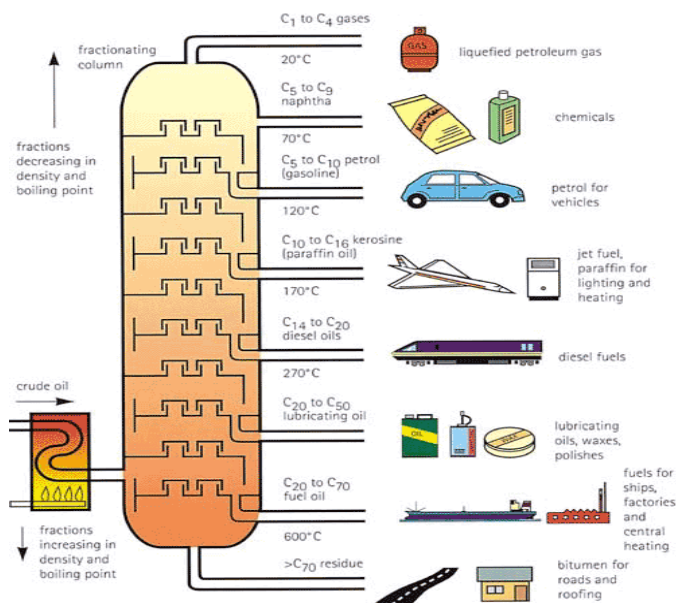


Figure 14 - Fractional distillation.

Source: <http://esfscience.wordpress.com/2008/09/08/fractional-distillation/>

3.2.2.1 Economic Issues

The production of petroleum distillates are much more complicated as compared to heavy fuel oil and with the increase in demand for the distillates due to the reduction of SO_x limits, will therefore drive the price for distillates higher especially when compared to heavy fuel oil. A study involving the analysis and review of the price levels of the different types of fuels, ranging from heavy fuel oil with sulphur content of 3.5 percent to

sulphur reduced heavy fuel oil of 1.0 percent, and distillates with a maximum of 0.1 percent sulphur show that the price of distillates by 2015 could range between USD 850 to 1,300. When the price is compared with heavy fuel oil of sulphur content of 1.0 percent, it means a disadvantage of approximately USD 300 to 600 per ton fuel⁹. The consequence of these is that operating ships in SECAs will become more expensive than in other areas. Hence, it raises concerns of disproportion in competition of shipping. Another mode of transportation replacing of shipping could evolve to reduce the cost impact.

Key ship owner and operator had also expressed concerns in the development of the implementation of global ECA, as they had opined that the quickest solution to meet the requirement will be turning to low-sulphur fuel, as compared to high value investment to alter the ship's structure¹⁰.

3.3 Greenhouse Gas (GHG)

It is through the influence of the Kyoto Protocol that makes shipping to take an accelerated step to put provisions in place to reduce ships' emissions. The protocol categorise shipping into two different types, i.e. domestic and international shipping. Domestic shipping is targeted at the developed countries (ie. Annex I). This group had officially committed to a reduction of 5.2 percent from 2008 to 2012 as compared with the 1990 level on four types of GHG (ie. CO₂, methane, NO_x, SO_x).

3.3.1 IMO GHG Studies

The 2000 IMO GHG study was the first study conducted to examine the status of air pollutants from international shipping. The study had identified that the main cause of

⁹ Reduction of sulphur content of shipping fuels further to 0.1% in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area, *Bremen, September 2010*.

¹⁰ Refer to interviews with *Zodiac and un-named shipowner*.

shipping emissions resulted from marine engine exhaust emissions. Hence, an analysis on the marine ‘emission inventory’ was carried out with the focus on bunker fuels, as it is the main feed to marine engines. The factors used were the fuel-consumption methodology and statistical emission model. Recommendations were then made to conduct further assessments on effects of NO_x, SO_x and CO₂ emissions from ships.

The second IMO GHG 2009 Study estimated the potential for reduction of emission using different technologies and practices, cost effectiveness and evaluation of policy options which are under considerations. The Study reaches several significant conclusions:

- In 2007, international shipping was estimated to have emitted 870 million tonnes, or about 2.7 percent of the global manmade emission of CO₂;
- Mid-range emission scenarios suggested that by 2050, without any reduction policies in place, ship emission may grow by 150 to 250 percent as a result of growth in world trade;
- A significant potential for reduction of GHG through technical and operational measures had been identified. If all measures are implemented, including reduction in operational speed, by 2050, it is estimated that the emission rate will reduce below the current levels on a tonnes/mile basis.
- With regards to emission trading, it was viewed as not viable for emission allocation, however a system of emission credits to ship owners for reducing emission below the baseline was considered possible. The evaluation of the report was deferred till April 2001, MEPC 46, where decision was made to form a working group to consider the issues on short and long term measures for reduction of emissions. In the December 2003 IMO assembly, MEPC was assigned to identify and develop mechanisms for reduction of GHG emissions from international shipping including development of a GHG baseline; the

development of a GHG emission index for ships. MEPC was also tasked to develop guidelines for application efficiency index and to evaluate technical, operational and market-based solutions.

The feasibility report carried out by IMO advocated an approach to explore feasibility of voluntary GHG limits or environmental indexing, and recommended that the work should preferably start on, the design of new ships and perhaps on existing ships and the prospect of ‘credit trading’ from additional abatement measures for new and existing ships.

Technical measures identified for reduction of shipping emissions include,

- Optimized hull shape and propeller design;
- Improved diesel engine efficiency;
- Waste heat recovery systems, hull and propeller maintenance; and
- Use of alternative fuels.

Operational measures include,

- Fleet planning;
- Use of higher quality fuel;
- Optimized weather routing and ‘just in time’ voyage planning.

The report also identified ‘slow steaming’ as the particular measure that would result in the highest achievement of CO₂ reduction; a speed reduction of 10% by the world fleet could reduce CO₂ emissions by 23.3 percent by 2010. If speed reduction is used in combination with technical and operational measures as mentioned above, there is a possibility of 40 percent CO₂ reduction by 2010 and 50 percent by 2020.¹¹ Taking the

¹¹ Study from Greenhouse Gas from Ships, Final Report to IMO, 2000, *MARINTEK, ECON, Carnegie Mellon, and DNV*.

recommendations from the study into consideration, MEPC had been tasked to development measures to curb GHG emissions from new ships.

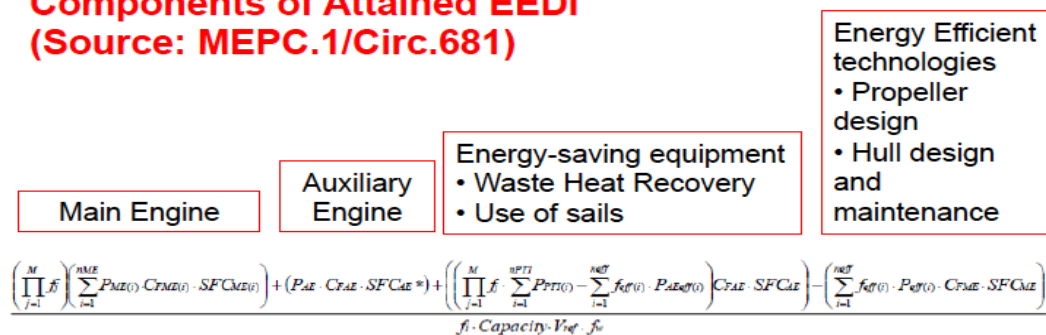
3.3.2 Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP)

At the 62nd MEPC session held from 11 to 15 July 2011, IMO had finally adopted the criteria for EEDI after several years of deliberation. EEDI is a design index meant for new ships to promote innovation and technical development influencing the energy efficient of the ship at the design stage, and a Ship Management Plan: for existing and new ships that incorporates the best practices for fuel efficiency for the operation of ships.

The objective of EEDI is to use the minimum required energy level to undertake the same transport work. This includes continuous challenging of the technical development of all related components influencing the fuel efficiency of a ship; and separating the technical and design-based measures in terms of operational and commercial.

The EEDI is based on a formula in IMO and the formula possess four element addressing important part of air pollution namely emissions from marine diesel engines, other energy-saving structural or technology on board and operational and design efficiency of ships. Following formula detailed the components of the formula. This formula is only applicable for new ships.

Components of Attained EEDI (Source: MEPC.1/Circ.681)



The CO₂ emission represents the total CO₂ emission from the combustion of fuel, including the propulsion and auxiliary engines and boilers, incorporating the carbon contents of fuels. The transport work is derived by multiplying the ship's capacity (dwt), as designed, with the ship's design speed measured at the maximum design load condition and at 75 percent of the rated installed shaft power.

IMO had set the reduction rate to three stages, the reduction during the first stage is set at 10 percent with five yearly reviews to keep pace with the development of new technologies. From 2025 to 2030, IMO has set the reduction to 30 percent as a mandated rate for most ship types. Nevertheless, it still invites various criticisms from the industry on the practicality of such a measure. The following table briefly summarises the disadvantages faced by the current EEDI formula.

Table 5 - Issues raised with regards to EEDI.

Performance measures	Issues	Possible impact
Limitation of installed power	Absence of speed factor	Affects operational model
Engine	Ineffective if ship is not at full speed	Increase in fuel consumption
Ship types	Formula incompatible for some ship types	Instability

Source: Summarised by author, master's dissertation, Malmo, World Maritime University.

Firstly, it was opined that it would be unsafe for bigger ships as the EEDI would reduce the installed power drastically. For example, in Phase 3 EEDI will require a VLCC to reduce its installed power by half. The proposed formula was found to have omitted the factor of speed, which is proposed to be studied at a later stage by IMO. This factor is seen to be crucial by the industry as it affects the operational model depending on the type of ship.

Secondly, the EEDI may be seen as ineffective, as compared with ships which are already on slow steaming. As EEDI principle is to limit the installed power, there will be a tendency for smaller bore and higher revolutions-per-minute-engines to be used. This is only effective when the ship is on full speed. On the other hand, if the speed of the ships is low, the ship that complied with the EEDI will experience a significant increase in wave resistance, which will lead to the fact that when compared with existing ships which are on slow-steaming, EEDI compliant ships will be more inefficient. IMO had qualified the arguments by indicating that it is a wrong concept to assume that a reduction in installed power will requires a reduction of engine bore and an increment in rpm. It counter-argued that the most effective way is to limit the “maximum” rpm which will result in increasing propeller efficiency; or to install one less cylinder which will result in less fuel consumption¹². IMO had also concluded that if the EEDI were implemented in 2013 for all new ships, it would remove 40 to 50 million tonnes of CO₂ from the atmosphere annually by 2020.

Thirdly, the applicability of EEDI on all ship types has also been questioned. Several renowned institutes had applied the EEDI formula on tankers and Ro-ro vessels and

¹² <http://www.imo.org/MediaCentre/HotTopics/GHG/Pages/default.aspx>

commented that strict application may caused ships to be unsafe¹³. Hence, further refinement of the EEDI formula will be required and should not be applied universally.

Unlike the EEDI, Ship Energy Efficiency Plan (SEEMP) is designed for existing ship to monitor its efficiency and optimize the performance of the ship. The objective of SEEMP is to develop a mechanism for the company to improve the ship's operation efficiency by linking the specific ships SEEMP to the company's energy management policy. The following figure illustrates the process of SEEMP.

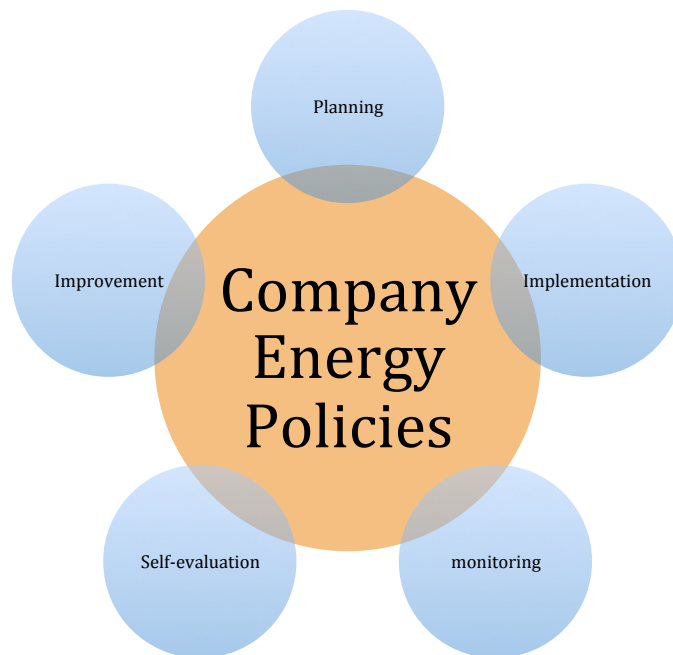


Figure 15 - SEEMP process.

Source: Summarised by author based on information in MEPC 59/24/Add1. Annex 19, master's dissertation, Malmo, World Maritime University.

¹³ Jack Devanney, head of centre for tankship excellence; Report on EEDI, prepared by Deltamarin for European Maritime Safety Agency; and The Energy Efficiency Design Index (EEDI) for Ro-ro Vessels by Stefan Kruger, Technische Universitat Hamburg-Harburg, Hamburg/ Germany.

3.3.3 Energy Efficiency Operational Indicator (EEOI)

The Energy Efficiency Operational Indicator (EEOI) is meant to enable ship owners and operators to measure their ships' energy efficiency level. This index is expressed in terms of CO₂ per ton mile, for measurement of a specific ship and make it available for comparison with other similar ships. It also acts as a monitoring tool and benchmark for the mandatory management tool for energy efficient ship operation (SEEMP).

3.3.4 Market-based Measures (MBMs)

The Market-based Mechanisms is referred to as a policy tool for reduction of air emissions. It was first introduced in the Kyoto Protocol as an additional means to assist the countries to meet their national goal towards emission reduction. The following figure shows list of mechanisms and measures being introduced or still pending evaluation in different sectors.

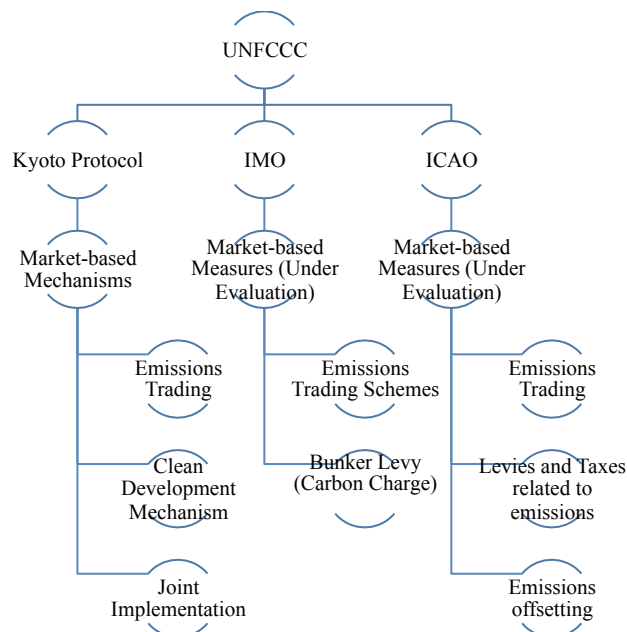


Figure 16 - Overview on types of Market-based Mechanisms/ Measures.

Source: Created by author based on information from research materials, master's dissertation, Malmo, World Maritime University.

The proposed maritime Market-based Measures (MBMs) serve two main purposes:

1. off-set the growing ships emissions in other sectors and provide an economic incentive for the maritime industry to invest in more fuel efficient ships and technology;
2. to operate ships in a more energy-efficient manner.

The MBMs proposals range from schemes for contribution or levy on all CO₂ emissions from international shipping, or only from ships that do not meet the EEDI requirement, via emission trading schemes (ETS), to schemes based on a ship's actual efficiency determined through its design (EEDI) and operation (EEOI).

3.3.4.1 Description of bunker levies

Carbon charge on bunker fuel

As discussed earlier, the main cause of emissions of SO_x and NO_x through combustion emits from the fuel consumed by ships. It appears that the most rational way to discourage the persistence usage of such fuel is to impose a carbon charge on bunker fuel. However, this policy will increase the cost of bunker fuel, and may result in some positive as well as some negative effects: reductions in the amount of maritime traffic, as some may chose alternative mode of transportation; efficiency improvements in marine engine and ship designs; efficiency improvements in ships operations; switching of ships types, such as ships with lower emissions level and higher efficiency counter; and lastly switching to alternative fuels¹⁴.

The charging of carbon taxes also faces political resistance. As the introduction of such an instrument will put countries with intensive industries to be less competitive in the

¹⁴ Study on Greenhouse Gas Emissions from Ships, March 2000, *MARINTEK*.

international markets due to the higher costs involved, unless a global use of common carbon charges on international shipping can be adopted.

The Oxfam and World Wide Fund (WWF) had published a report in September 2011 on a proposal to coming COP17 in December this year. The proposal calls for imposing carbon tax on international shipping, which is belief to reduce emissions from ships significantly by 33 percent by 2020 as compared with EEDI, which will only reduce emission by 1 percent by 2020. The revenue generated will be divided between the ‘Green Climate Fund’ with a portion retain for maritime sector, and as compensatory rebates for the developing countries. The following figure illustrates the proposal in detailed.

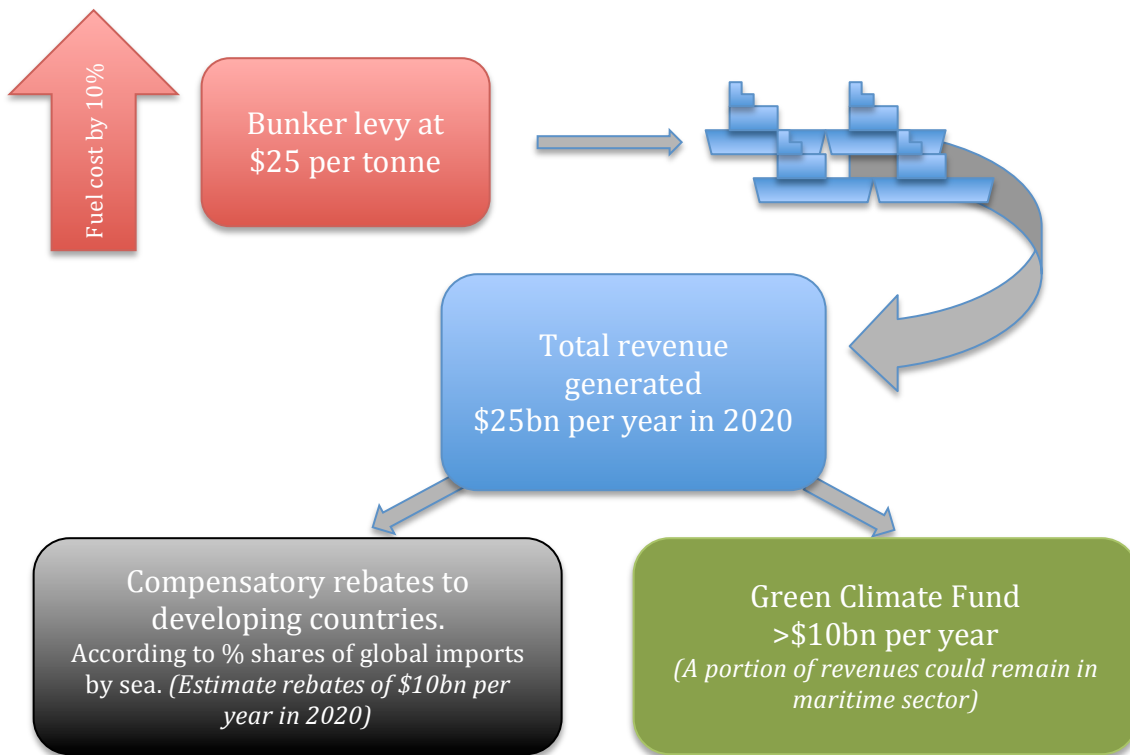


Figure 17 - Potential scale of revenues with implementation of bunker levy as proposed by Oxfam and WWF

Source: Created by author based on information from Oxfam/WWF analysis report, master's dissertation, Malmo, World Maritime University.

The proposal is believed to raise bunker price by 10 percent, which is 0.2 percent of the total value of global trade. Oxfam and WWF opined that this would only have marginal impact to the global patterns of trade. The report also indicated that shipping would be an easy source of revenue for the UN Green Climate Fund.

Emissions Trading Schemes (ETS)

The objective of the Emissions Trading Schemes (ETS) is to provide economic incentives for achieving reduction in emissions targets. Currently, there are several formats of Emissions Trading Schemes (ETS) proposed by Norway, United Kingdom and France. These proposals vary from implementation with a cap and without a cap on the emission rate, and generally most of these proposals suggested for international trading of credits in auction. To date the proposals are still under the evaluation of the Expert Group giving priority to the maritime sectors of developing countries, least developed countries (LDCs) and Small Island Developing States (SIDs).

3.4 Conclusion

In this chapter we had discussed the elements regulated in MARPOL Annex VI for air pollutants from shipping which covers the fuel oil used supplied to and used on board ships, and the exhaust emissions from ships. It has also discussed the ongoing mechanisms and measures, which are under evaluation to further, reduce GHG emissions from international shipping such as EEDI, SEEMP, EEOI and MBMs. We will now look at the development technologies for reduction of emissions from ships.

4. EFFORTS & TECHNOLOGY FOR REDUCTION OF EMISSIONS FROM SHIPS

Efforts to minimizing the emissions of SO_x, NO_x and GHG from ships have been continuously evolving. Based on the current developments, the measures can be divided into three main categories: technology and designs on ship to improve the efficiency and reduce exhaust emissions; fuels used; and eliminating ship emissions in port totally by switch to shore based energy supply.

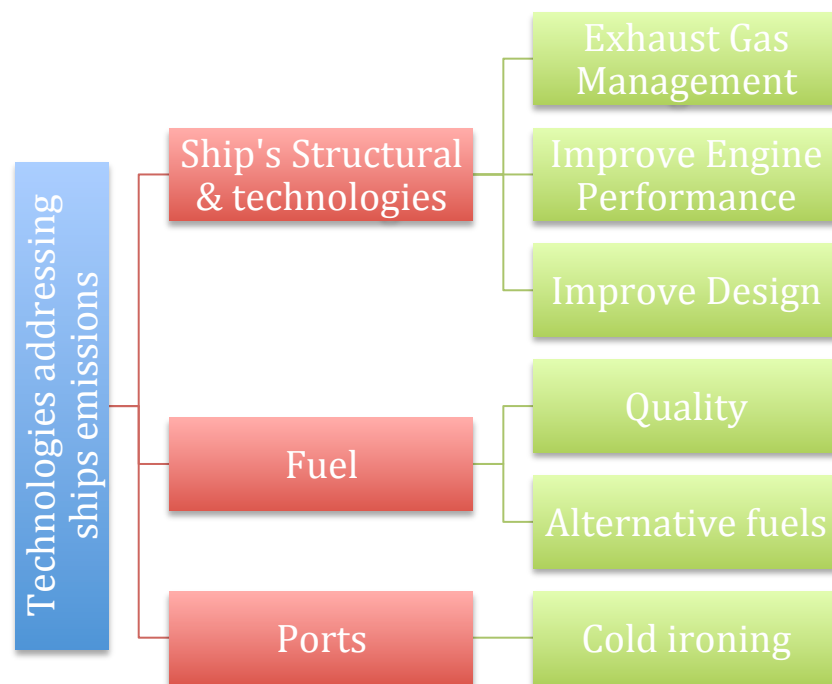


Figure 18 - Efforts and technologies introduce or understudied currently.

Source: Unpublished, master's dissertation, Malmo, World Maritime University.

4.1 Ship's Structural & Technologies

Improvement of ship's structural and to enhance the ship's operational efficiency has been one of the highlights to reduce the GHG emissions from ships. Several technologies have been developed to reduce the exhaust emissions from ships. However, these new

developments demand the highest investment value from the ship owners. Hence, most shipping companies are taking a “wait and see” approach on the latest policies development from IMO prior to making big investment decisions to their business strategy. This chapter will discuss some of the current technologies and ships design proposed.

4.1.1 Exhaust Gas Management

In order to resolve the issue of shipboard pollution yet avoiding incurring prohibitive costs, several companies have relied on either one or a combination of new technological developments or alternative fuels to address these environmental issues.

4.1.1.1 Scrubbers & Water-based technology/ Exhaust Gas Recirculation (EGR)

Sulphur Oxide (SOx) emissions can be reduced by burning lower sulphur contents fuel known as distillate fuels, or for a longer term saving to install technology to treat gas emissions, known as scrubbers and exhaust gas recirculation (EGR). Scrubber decreases the contents of sulphur oxide and particle levels in the exhaust gases by capturing them in an alkaline liquid stream. Alternatively, seawater can also function as scrubber liquid. However, seawater scrubbers are raising concerns that the effluents release may cause harm to the ecosystem as they will also be acidic.

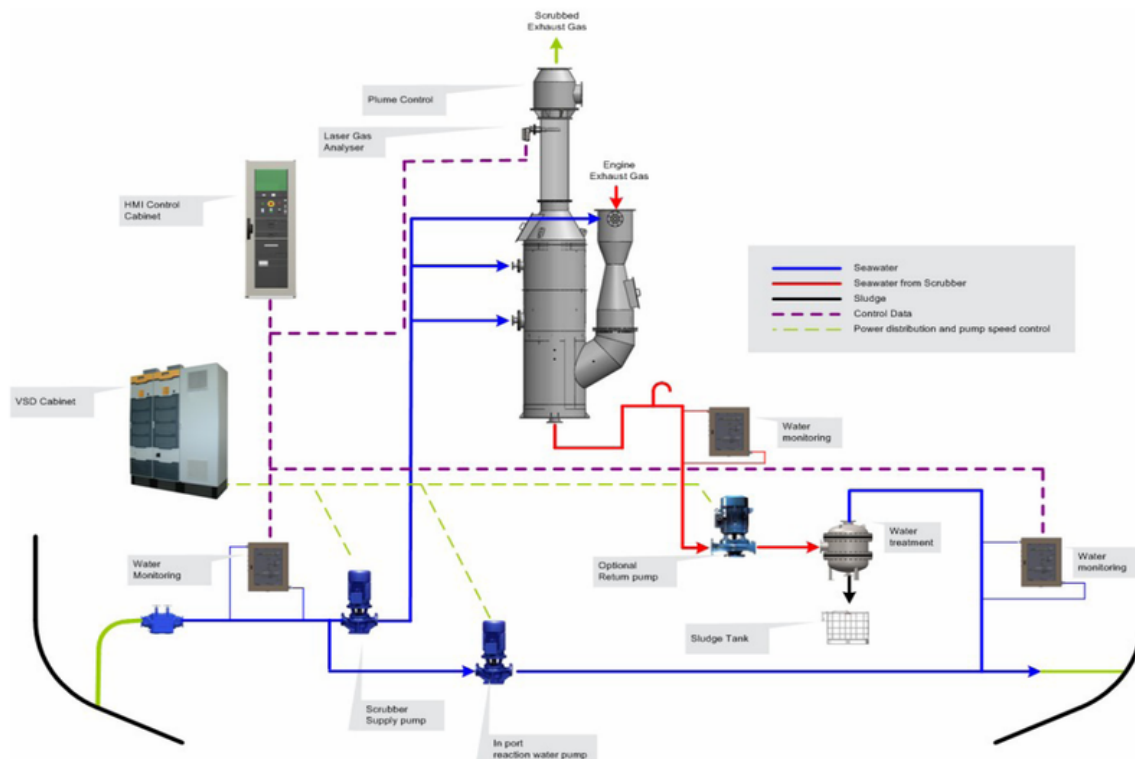


Figure 19 - Typical layout for seawater scrubber.

Source: <http://www.greencarcongress.com/2011/01/ports-of-los-angeles-and-long-beach-to-test-new-seawater-scrubber-device-to-cut-vessel-emissions.html>

4.1.2 Improvement in Engine Performance

Engine manufacturer MAN Diesel and Turbo (MAN) has developed “Approved Methods” for retrofitting 1990s-built marine engines to meet Tier-I emissions standards. The solution will cut about 60,000 tonnes of NO_x emissions annually, and includes adjustment and certification of the engines after the procedure. These retrofits, essentially comprising the installation of modern, slide-type fuel valves (replacing injection valves in old models), will significantly reduce exhaust emissions. The improved fuel-injection technology will also lower emissions of other exhaust gases including carbon monoxide, unburned hydrocarbons and particulates, yet will not increase fuel consumption. Furthermore, the low-load performance of the engine will be improved and visible smoke

minimised. According to MAN, about 800 engines will undergo the Approved Methods retrofit solution over the next few years.

4.1.3 Improvement in Ship's Designs

For the longer term, DNV showcased their Quantum concept container ship, which would allow a payback time of about 2 years for the improvement on the hull shape and about 12 years for investments allowing for switching to liquefied natural gas (LNG) as a fuel using an LNG price equal to the price of marine gas oil (MGO). The Quantum is designed to carry more cargoes using less fuel and its electric propulsion is powered by four dual-fuel engines using MDO or LNG and the ship has a design speed of 21 knots with the ability to boost speed by several knots and also slow-steam down to less than 10 knots.



Figure 20 - DNV's Quantum concept container ship.

Source: DNV.

4.2 Fuel

Fuel oil used for combustion purposes on board ship has been identified as one of the main contributors to air emissions from ships. Due to the molecules components within the fuel oil, different levels of SO_x contents are emitted when heavy fuel oil is used for combustion.

4.2.1 Quality

Fuel oil quality is currently regulated under MARPOL Annex VI Regulation 18. However, reliance on the only option of low-sulphur fuel or distillates may not be operationally or economically viable. As the costs of such fuels may escalate due to the global demand. Hence, the maritime industry has been actively researching on possible alternative fuels for ships.

4.2.1.1 Alternative fuels

There are a few alternative fuels for replacement of the marine fossil fuels. The following table summarises the types of alternative fuels that have been explored to date, and some of the advantages and disadvantages of each fuel option.

Table 6 - Advantages and disadvantages of currently identified alternative fuels.

Alternative Fuels	Advantages	Disadvantages
LNG	Reduction of NOx emissions by 90%	<ul style="list-style-type: none">• Modifications of storage tanks• Void spaces on deck• High investment
Hydrogen	Zero emissions	<ul style="list-style-type: none">• Power limitation• Understudy option by using aluminum-based alloys
Nuclear Power	Eliminates emissions of GHG, SOx, NOx and PM	<ul style="list-style-type: none">• Transfer to upstream emissions• Generates nuclear wastes

Source: Unpublished master's dissertation, Malmo, World Maritime University.

Liquefied Natural Gas (LNG)

Liquefied natural gas (LNG) is one of the more common options currently. It was first introduced on LNG tankers and is being introduced to other carriers. However, there are

issues that are likely to hold back the development of LNG as bunker fuel. Firstly, modifications such as installation of storage tanks and costly engine changes will need to be carried out on the ships in order for the existing ships to be able to use LNG as an alternative fuel. Under the current IGC Code, LNG storage tanks are prohibited in close proximity of ships' accommodation unlike the fuel tanks for HFO and distillates. In such circumstances, there will be a requirement for void space on deck, which will affect the cargo capacity of the ship and the tonnage figures. In addition, the investment of such modification may be quite handsome, thence, this alternative option may not be too attractive unless amendments are made to the IGC Code to provide exemptions under this situation, or if the price of the LNG is lower than low sulphur fuel in the future. Secondly, there is currently a lack of infrastructure for bunkering ports for LNG. Nevertheless, if the change to LNG is feasible, it will reduce the NO_x and PM emissions by approximately 80 percent¹⁵ as compared to marine fossil fuels, and SO_x emissions are nearly eradicated. If the combustion system on board ship is well design, using of LNG as bunker fuel on board ships will also result in a reduction of approximately 25 percent¹⁶ of GHG emissions.

Other advocates of alternative fuels such as energy and climate change adviser, Lord Ronald Oxburgh, said that replacing bunker fuel with liquefied natural gas (LNG) could offer “enormous benefits” to the shipping industry by not just reducing green house gases but also sulphurous gases as well. DNV has also stated that the global recoverable supplies of natural gas are now estimated at 250 years at current consumption levels compared with 50 years for oil.

¹⁵ Exhaust emissions from ships engines – significance, regulations, control technologies, *Laurie Goldworthy*.

¹⁶ *ibid*

Hydrogen

Beyond LNG, progress had also been made to use hydrogen as a fuel. Researchers at a US university are claiming a breakthrough in developing technology that would allow hydrogen to be used as a fuel for ships. A method was found that uses aluminum and a liquid alloy to extract hydrogen from seawater. A posting on the Purdue University's website said the development represented "a potential replacement for gasoline and diesel fuel in marine applications." Hydrogen generated by the technology could be fed directly to an internal combustion engine. This is important because it might have many marine applications, including cruise ships and tankers. The method also makes it unnecessary to store hydrogen, a major challenge in using hydrogen to power ships.

Nuclear Power

Interest in the potential of nuclear propulsion for ships has been growing as shipowners explore alternative fuels that will be able to meet future emission restrictions. Nuclear power/ energy makes no contribution to global warming through the emission of carbon dioxide (CO₂) and also produces no notable sulphur oxides (SO_x), nitrogen oxides (NO_x), or particulates.

Nuclear power is, however, not 'clean' or 'emission free'. The use of nuclear power transfers the emissions to the upstream nuclear fuel production stage and pollution to the downstream nuclear waste dumps as the production of nuclear fuel produces tonnes of greenhouse gases and toxic and radioactive by-products, such as carbon-14, and that there are open air nuclear waste dumps at Seversk in Russia.

Other technological proposals

A research consortium, which includes Lloyd's Register, Enterprises Shipping and Trading, Hyperion Power Generation and BMT, are examining marine applications for small modular reactors (SMRs). The consortium of British, American and Greek interests will investigate and search for new designs that can deliver safer, cleaner and commercially viable forms of propulsion for the global fleet. They believe that nuclear propulsion is technically feasible and has the potential to drastically reduce the CO₂ emissions caused by commercial shipping. The consortium believes that SMRs, with a thermal power output of more than 68 megawatts, have the potential to be used as a plug-in nuclear 'battery'. The research is intended to produce a concept tanker-ship design based on conventional and 'modular' concepts.

Similarly, the marine engine manufacturer Wartsila has stated that customers are "increasingly looking for optimisation of their assets to reduce both costs and their environmental footprint." Wartsila has gone on to state that as an example of its customers' increased focus on reducing their environmental footprint and fuel costs, Wartsila has signed a "turnkey contract" with Tarbit Shipping of Sweden to convert a product tanker to LNG propulsion. "The conversion of the 25,000 dwt product tanker Bit Biking will enable the vessel to qualify for lower emission taxes under the Norwegian government's fund scheme. The project to convert the ship's main propulsion to LNG is the first of its kind in the world", it noted. The installation of Wartsila Slow Steaming Upgrade Kits with A.P. Moller Maersk Group will lead to fuel savings as well as reduced CO₂ emissions. Wartsila expects environmental upgrades and conversions to continue. The company has launched the Wartsila Ballast Water Treatment solution, which

provides customers with a reliable means to respond to the requirements set by the IMO, and to additional requirements by maritime authorities.

After discussing the various options of alternative fuels, the actual efficiency will be crucial to ship owners and operators to make decision on which will be the best option. Lloyds list had conducted a study to make a comparison on the efficiency gains from various types of alternative fuels proposed. The following table describes the gains in percentage. Other than nuclear power, LNG appears to be the most viable alternative fuel option.

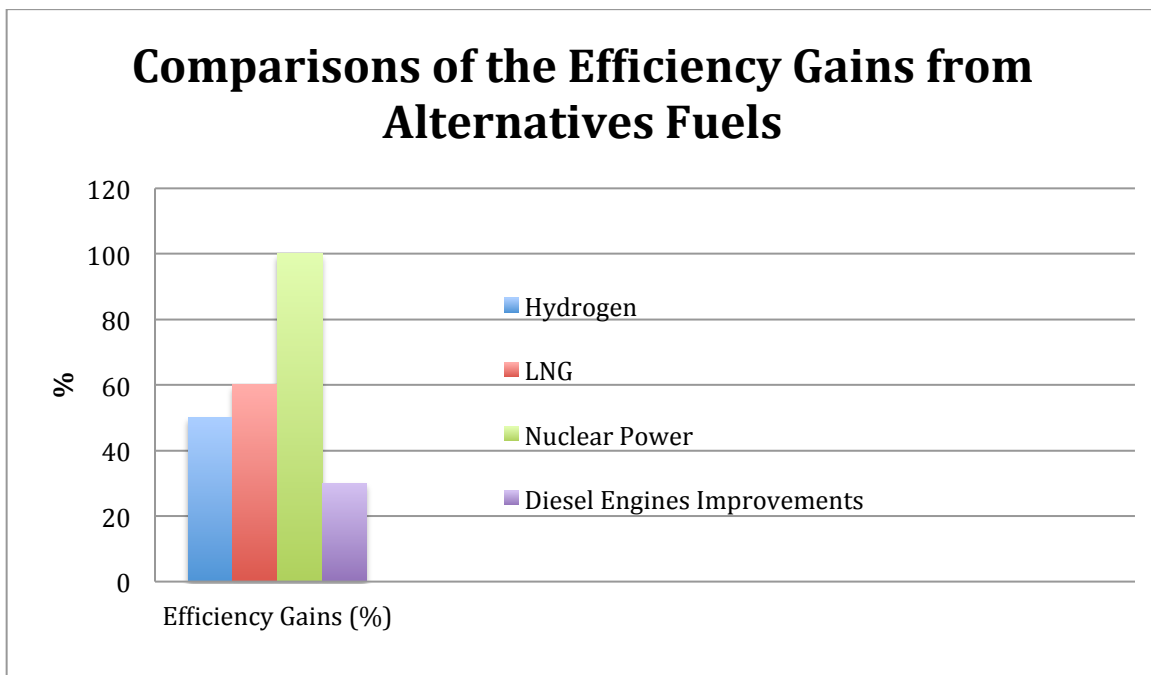


Figure 21 - Comparison of the efficiency gains from alternative fuels.

Source: Created by author with information from www.lloydslist.com, master's dissertation, Malmo, World Maritime University.

4.3 Port

Other than efforts to reduce ships' emissions by modification on the ships itself, using alternative powering method has also been looked at. Ports been the key for sea

transportation has also starts to develop technology to eliminate ships' emission while the ships is at berth.

4.3.1 Cold Ironing

Cold ironing, also known as shore power is one of the technology that eliminates SO_x, NO_x and CO₂ emissions from ships to almost zero level when the ship is at berth. The ship will plug into the port electric grid while in port and cease using it's diesel auxiliary engine and boiler. Currently only a few ports in the USA including California are providing such technology in their ports. However, there are hiccups faced in implementing this technology further. The 'plug-in' point is not universal. So far, in this case, ships will be required to be equipped with different 'plug-in' designs when calling at different ports. It was also discussed that this technology is not an ideal approach for reduction of emissions globally, as emissions from shipping may be transferred to land based power stations instead. Nevertheless, cold ironing is not a permanent solution for ship emissions as it can only be made used of when the ship is in port.

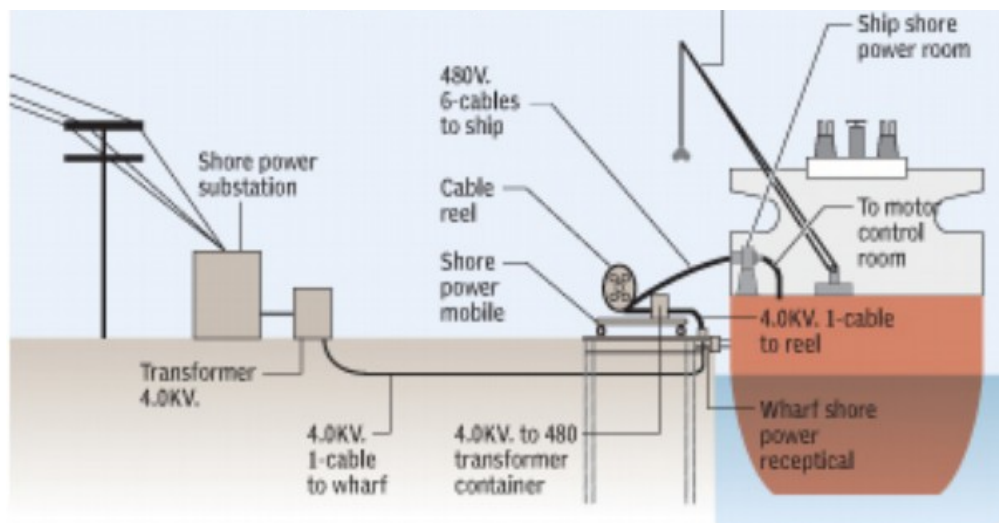


Figure 22 - Typical layout for cold ironing installation in port.

Source: <http://www.shoreportshippower.com/>

4.4 Conclusion

This chapter has summarised the three different areas of technologies developed to address the ships' emissions, and alternative fuels in replacement of fossil fuels. It also discussed on the pros and cons of each of the technologies and alternative fuels proposed thus far. Nevertheless, these technologies are not widely make use of by the shipping industry at the moment as most of it requires big investment on the ship's infrastructure, other than cold ironing. However, cold ironing also possess it's own problem such as unification of shore connection, and limited availability in ports. Now that we have seen the existing and developing technology and alternatives, we will look at other form of methods to reduce ships' emissions in port, i.e. incentive schemes.

5. ECONOMICAL INFLUENCES /EFFORTS FROM VARIOUS PORTS

Prior to the agreement was reached at the 62nd MEPC, several nations had come up with different policies to cap emissions within their jurisdictions. Some countries and regions had gone ahead to implement legislation or voluntary programmes to reduce emissions from ships within their jurisdictions. Some went ahead with mandatory requirements under their legislation, but providing certain incentives if ships were able to comply, while the rest went with voluntary agreement programmes, while at the same time also provide incentives to ships that voluntarily take necessary actions to reduce emissions while in port. Voluntary programmes may range from agreements or a declaration of intent between the industry, or, a company with the government. Such agreements or declaration mainly focuses on the on reduction of emissions with various ways of implementations such as fuel switching, special technology, operational measures etc.

5.1 Green Port Developments

Over the past few years, there is an increased focus on the marine environment, which has led to corresponding calls to regulate international shipping more closely, as well as efforts to encourage sustainable developments of seaports. As a result of this burgeoning “Green Port Culture”, many ports, in particular those in Europe and North America, have voluntarily adopted environmentally-effective practices and operations, like the installation of solar panels on their buildings, provision of shore power for vessels at berth and regulation of emission from port equipment, prime movers and other machinery.

Ports also come together through collaborative agreements to not only encourage the adoption of best practices for terminal operators, but also introduce schemes to incentivise ships calling at their ports to reduce their pollution level.

5.1.1 EU Regulations

The EU directive 2005/33/EC¹⁷ regulates the limits of sulphur content of marine fuel oils. The directive prohibits the use of marine fuel oils with sulphur content above 1.0 percent after July 2010 for passenger ships that ply regularly at community ports. This restriction also applies to ships that transit through SOx emission control areas (SECA) specified by IMO. Restrictions are also placed on exhaust gas cleaning technology such as seawater scrubbers. It has to show that the resultant emission has no adverse effects on the ecosystems. On 1 January 2011, EU had implemented its requirements for ships that transit within EU ports and inland waterways to burn marine fuel oils with sulphur content of 0.1 percent or less.

5.1.2 US Regulations

The MARPOL Annex VI requirements came into force on 8 January 2009 in US as part of the Maritime Pollution Protection Act of 2008. This enactment emphasizes the greater awareness raised in the US with regard to ship emissions. Because of the federal structure of US, the state has the power to introduce local regulations, which may be more stringent.

5.1.3 California Regulations

The State of California had promulgated national regulations to curb SOx, NOx and Particulate Matters emissions for ocean-going vessels within its internal waters and

¹⁷ EU directive is a legislative act of the European Union which requires the member states to comply without dictating the means of achieving that result.

twenty-four nautical miles from its baseline. These regulations specified the sulphur content limits for marine gas oil (MGO) and marine diesel oil (MDO) in two parts: for the use of auxiliary diesel engines and main engines and auxiliary boilers as follows:

1. Auxiliary diesel engines,
 - a. From the entry of the regulation till 30 December 2012, MGO with maximum SOx content 1.5 percent, or MDO of maximum SOx content of 0.5 percent may be used;
 - b. From January 2012, MDO and MGO with maximum SOx content of 0.1 percent shall be used.
2. Main engines and auxiliary boilers,
 - a. From 1 July 2009, MGO with maximum SOx content of 1.5 percent, or MDO of 0.5 percent may be used;
 - b. From 1 January 2012, MDO and MGO with maximum SOx content of 0.1 percent shall be used.

A detailed comparison table on the implemented and adopted regulations (to be in-force in near future) is drawn up in Appendix 3.

5.2 Low-sulphur Schemes on voluntary basis

- Several container-shipping lines have signed up for voluntary low-sulphur schemes being subjected to trials in Chinese and US ports. The Taiwanese line Evergreen has announced its participation in Hong Kong's Fair Winds Charter and the port of New York and New Jersey's Ocean-Going Vessel Low-Sulphur Fuel Program. The programme is an action element of the Clean Air Strategy and encourages operators of ocean-going vessels calling at certain PANYNJ marine terminals to use low sulphur fuel, and reduce vessels' speed to an average of 10

knots or less. The programme will reimburse vessel operators for 50 percent of the cost difference between Marine Gas Oil (MGO) or Marine Diesel Oil (MDO), and IFO380 in their main engines while operating within 20 nautical miles of the Port of NY & NJ.

- Similarly, container carrier APL said its ships would use low sulphur fuel when calling at terminals in the Port of New York and New Jersey. The agreement is part of a port authority program designed to curb emissions in New York Harbour. Under the plan, APL vessels will use low-sulphur fuel in auxiliary generators while berthed. The port authority will reimburse half of the added cost APL incurs by using low-sulphur fuel. According to APL, low-sulphur fuel can reduce particulate matter emissions by 75 percent and sulphur oxides by more than 85 percent. APL has long been part of similar programs at the ports of Los Angeles, Oakland, Seattle and Vancouver, British Columbia.
- In September 2010, Maersk Line initiated a switch to using cleaner, low-sulphur fuel when it calls into Hong Kong. The approximate 850 port calls a year by Maersk at Hong Kong is estimated to cost an additional US\$1 million annually to the company. This kick-off is the first voluntary fuel switch scheme in Asia. APL followed the trend by switching over to low-sulphur fuel in Hong Kong from October 2010.
- In Hong Kong, Evergreen will use fuel with a sulphur content of under 0.1 percent from the beginning of November 2010 until the end of December 2012 and will involve its ten most environmentally friendly vessels. Hamburg Sud and Alianca are testing the use of low sulphur fuels while at berth in Hong Kong and are participating in an initiative to cut emissions at the port. The two companies

are joining the Fair Winds Charter Initiative which aims to sustainably improve air quality in Hong Kong and the Pearl River Delta.

- On 12 April 2011, Singapore has launched a series of green initiative programmes – ‘Green Ship Programme’, ‘Green Port Programme’, and ‘Green Technology Programme’, following a voluntary scheme called the ‘Green Pledge’ with 12 organizations pledging their efforts to promote and undertakes environmental friendly and energy efficiency practices. The details of these initiatives will be further discussed in the following chapter.
- The Republic of Korea¹⁸ (ROK) has two strategies in the adoption of air emission control plan. Firstly, the implementation of international instruments to the national industries such as, the shipping industry, shipbuilding industry and oil refinery industry to ensure they meet international requirements. This will fulfill ROK’s responsibility as a flag State. Secondly, the Government has the long-term plan for the preservation of air from land and ships in order to foster the sustainable development of land and sea under ‘the National Green Growth Policy’. According to the national policy, not only emission of NOx and SOx but also other green house gases will be controlled strictly in all areas of industry.

5.3 Index measurement Schemes

Unlike the direct incentive schemes as describes above. The “Index Measurement Schemes” takes the approach of measuring the operational efficiency performance of the ships and provides rewards and recognition to the ship owners. These schemes are normally aim at a larger implementation area beyond the State’s own ports.

¹⁸ Based on interview via questionnaire with Ministry of Land, Transportation, and Maritime Affairs of Korea.

5.3.1 ESI launch in 2011 with clean ships to be rewarded in European ports

The International Association of Ports and Harbors (IAPH), backed by five major European Ports, had launched a scheme aimed at significantly reducing vessel emissions. Commencing Jan 2011, the World Ports Climate Initiative (WPCI) will introduce the Environmental Ship Index (ESI) - an international standard for calculating emissions by ships. Making use of the index, ports and other nautical service providers will be able to reward low-emission ships, and contribute to encouraging sustainability within the sector. Participating vessels will receive a certificate that may form the basis of a reward system employed by ports and other nautical service providers, discounting port dues, rates and alike. The ESI identifies those seagoing vessels that perform ahead of standards relating to emission reduction required by the current MARPOL Annex VI standards for nitrogen oxide (NOx) and sulphur oxide (SOx). In addition, the ESI also tests the presence of a management plan for greenhouse gas emissions of a particular vessel. Five initiator of the project – Hamburg, Bremen, Amsterdam, Rotterdam and Antwerp – have all indicated that they will use the ESI to reward clean ships, as well as promote sustainability.

ESI-registered vessels of all types that exceed the current minimum IMO environmental standards will be in line for a rebate at half a dozen hubs, which include Bremen, Le Havre and Amsterdam. Each individual port will set its own qualifying benchmark, with Amsterdam indicating that its rebates will begin at an index score of 20 or above, while the percentage level of rebate will also be left to each port. The Port of Rotterdam would apply an average 5 percent rebate for complying vessels, which it estimated as a 1 percent overall annual rebate, implying an annual ESI cost of around \$3 million euros in 2008. The Port of Amsterdam has stated that a typical 10,000 tonne vessel scoring above 20 index points could be in line for a \$300 euros rebate on port dues of around \$8,000 euros. The index shows the environmental performance of ships in terms of their emissions of air pollutants (NOx and SOx) and CO₂.

5.3.2 Carbon Disclosure Project (CDP)

DP World, which operates more than 50 container terminals across the world, has joined the Carbon Disclosure Project (CDP). CDP was established in 2000 and it acts as a disclosure and reporting framework. It is used by 3,000 of the world's largest companies to report their GHG emissions and climate change strategies. The move reflects the port operator's broad base and global sustainability programme. For several years, DP World has been introducing new/retrofitting certain existing handling equipment in its terminals while implementing a range of 'green business practices' as it has sought to reduce its environmental footprint. DP World has indicated that the group has a five-year plan in place to reduce emissions by 27 percent. In a recent public filing to the CDP, the group said its greenhouse gas emissions at its operational terminals totalled 830,715 tonnes of equivalent CO₂. This compared with 867,533 tonnes in 2008.

5.4 Conclusion

It is instructive to explore the benefits of mandatory legislation versus voluntary policy approach. At a quick glance, voluntary programmes may appear to be weaker policy as compared with mandatory legislation. As mandatory legislation ensures a level playing field requiring all ships to comply with the standards and failing so it will be penalized. Commercially this may be an ideal approach, as all ships are required to make similar investments to achieve the given target. On the contrary, this approach may not encourage any further initiatives or innovation to do more than what is required. The voluntary policy may appear to have an upper hand on this part. In this approach, only companies and industries that are willing or are ready to take a step further will come forward to make such commitments. Their initiatives are partly compensated through incentives such as reduction of port dues, or indexing efficiency programmes. The bigger benefit of this approach is that, the company or industry which makes such a commitment will gain public awareness on their commitment and this is a plus point in terms of business branding and strategy, which will not be visible in mandatory legislation.

After analyzing the different incentive approaches by major ports, we will discuss the approach by Port of Singapore towards reduction of ships' emissions in port and from its flagged ships.

6. CHALLENGES FACED BY SINGAPORE IN ENFORCEMENT OF EMISSIONS CONTROL POLICIES

Ensuring a sustainable clean and green environment has always been the motto for Singapore. This is carried out at the national level through various programmes, such as pollution control, waste management and energy efficiency.

The raise of international awareness on reduction of emissions from ships is also part of the reason for Port of Singapore to embrace policies to reduce air emissions from ships in port, and for ships registered under Singapore Registry. In April this year, Maritime and Port Authority of Singapore (MPA) had introduced several “green” measures to promote environmental friendly practices in port.

6.1. Description of Singapore’s ‘Green’ Policy

Singapore’s maritime ‘Green Initiative’ is summarized in the following table. Generally it is a three-pronged approach targeting all maritime related audiences, ie. Singapore Register Ships, Ocean-going ships entering Singapore waters, and local harbour craft and terminals.

Table 7 - Singapore's maritime 'green' initiatives.

“Maritime Singapore Green Initiative”			
	Green Ship Programme	Green Port Programme	Green Tech Programme
Target audience	SRS vessels	Ocean-going vessels entering port	Local maritime operators
Considerations	Encourage reduction of GHG emissions	Encourage reduction of air pollutants	Encourage adoption of green technologies
Target emissions	CO ₂	SO _x NO _x	CO ₂ SO _x NO _x
Target companies	Shipping Lines		Terminal, shipping lines & harbour craft operators

Source: Maritime and Port Authority of Singapore, master’s dissertation, World Maritime University, Malmo, Sweden.

- The 'Green Ship Programme' objective is to encourage the reduction of GHG emissions from the Singapore Register Ships. The main determining factor for compliance under this part is the Energy Efficiency Design Index (EEDI) measurements. The incentive under this programme consists of both finance and recognition: issuance of 'Green Recognition' letter and 'Green ship of the year' award, and monetary rewards of up to 50 percent reduction in Initial Registration Fees and 20 percent rebate on Annual Tonnage Tax. The following flow chart briefly describes the procedure of qualifying a Singapore Register Ship as a 'Green Ship'.

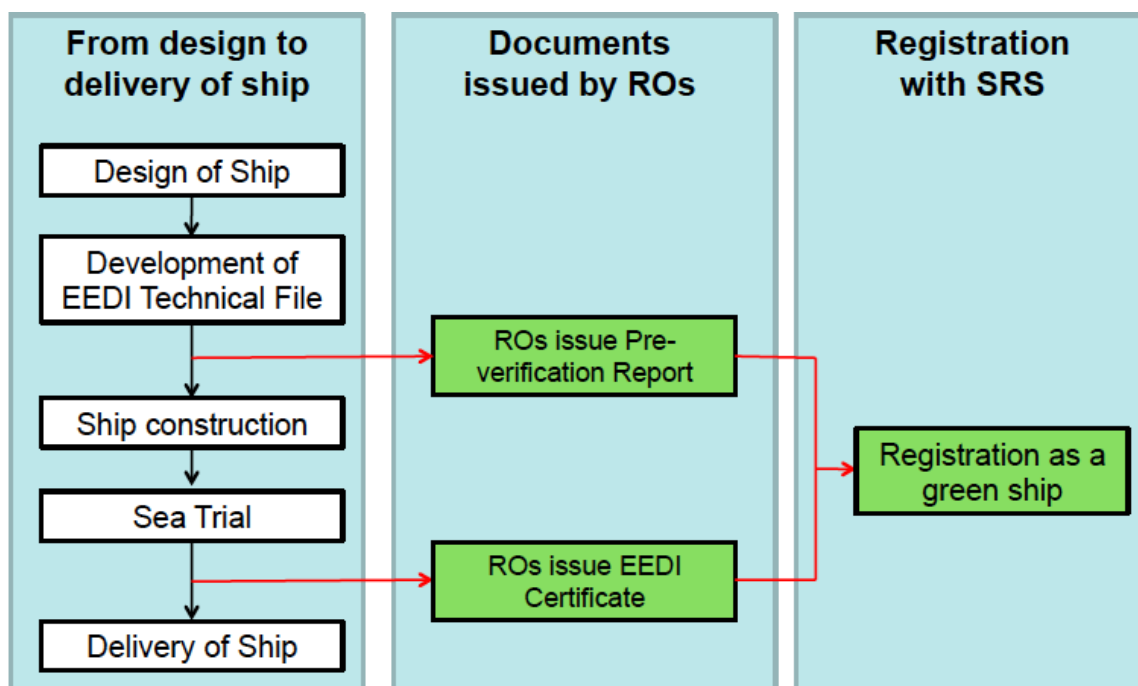


Figure 23 - Procedure of qualifying as a 'Green Ship' under Singapore Registry.

Source: Summarized by author based on information provided by Maritime and Port Authority of Singapore, master's dissertation, World Maritime University, Malmo, Sweden.

- The ‘Green Port Programme’ is an initiative targeted at ocean-going ships entering Singapore waters. The aim is to reduce the emissions of SO_x and NO_x while the ships is operating within the port. There are two main criteria under this programme, the use of type-approved abatement or scrubber technology; and use of low sulphur fuel within the port limits (<1.0% SO_x content). Ships that are able to comply with the above conditions will qualify for a 15 percent port due concession. The determining factor for compliance under this part is based on a declaration by the ship that it has complied with the programme’s criteria.
- The targeted groups under the ‘Green Tech Programme’ are the local shipping lines, harbor craft operators, and Terminals. The criteria for qualifying under this programme are that presentation of original projects that shows reduction in emissions of SO_x, NO_x and CO₂. However, the system integration design and retrofitting or installation has to be done in Singapore.

6.2 Challenges Faced

Although Singapore stands as the World’s top bunkering port, it faces numerous challenges in effectively implementing emission reduction measures due to several reasons such as the following:

- Geographical constraint. Singapore is situated among the neighbouring countries of Peninsular Malaysia and Indonesia. Currently, a ship that is undertaking the ‘Green Port Programme’ will shift over to low sulphur fuel when it is in Singapore port waters, which is less than 3 nautical miles away from the main island. Ships that are transiting in channel in between Singapore and Malaysia may not be required to shift over. Hence, the effectiveness of reduction of emission impact may be questionable.

- As the World's top bunkering port, Singapore faces challenges and pressure to promote the usage of low sulphur fuel to support the reduction of emissions from ships. However, economically this will have a substantive impact on the local bunker industry if the supply of low sulphur fuel is not readily available, ie. supply vs. demand. Technically, further investment will also be required from the bunker tanker operators to provide better segregation for the distillates to ensure the quality of the fuels.
- Singapore presently also stands as the world's busiest port with approximately a thousand movements per day. With the high traffic density and ships arrivals, physical checking for compliance on each ship will be an uphill task. Enforcement – with the high number of arrivals, it is almost impossible to have detailed checks on compliance. With that, it deduces on the calculation method for ships that can be qualified for the incentive schemes.

6.3 Conclusion

Singapore has take two main approach when introducing policies to reduce air emissions from ships, i.e. its international obligations as a member state to IMO and MARPOL Annex VI, and domestically as a responsible coastal state. It has promote the reduction of air emissions from ships by providing incentives to it's flagged ships, and domestic harbor craft and ships calling at it's ports. It also promotes the local terminal by providing research funds to local companies in developing more innovations for reduction of air emissions. These steps are a good beginning to prime for bigger steps to be taken in the future. Been geographically situation within other two countries (i.e. Peninsular Malaysia and Indonesia) and the Straits of Malacca and Singapore the world busiest straits, regional efforts may be the next steps to look at to promote reduction of air emissions from ships.

6.4 Recommendations

As mentioned in this chapter, the voluntary measures introduced by Singapore are pretty recent (April 2011) and it covers the three main areas: Singapore flagged ships, ports and terminals operating in Singapore, and harbor craft and foreign ships calling Singapore. Hence, there should be a period of ‘observations’ to see if these measures need further improvement and adjustment. The following recommendations are to fill the gaps that was not covered in the measures introduced and to achieve a better resultant of the ‘green’ initiatives adopted by Singapore, it is recommended to explore the following factors in the future:

- In order balance the Singapore’s top bunkering port position, with policy of been a responsible flag and coastal state, MPA may like to look at mechanisms to encourage the usage of low-sulphur fuel. Higher incentives in terms of port due reduction may be provided if ships loads and burn the low-sulphur fuel in Singapore port.
- Improve the effectiveness on the effort on reduction of ships emissions, the formation of a regional cooperation mechanism in terms of emissions reduction policies for GHG to achieve more effective results in improving of air quality in the region since the countries are closely situated. It can be approached through tripartite agreements with proposal to IMO for adoption.
- With high vessel arrivals, it is difficult for the limited resources of PSC officers to conduct 100 percent checks on the energy efficiency index. Since in the near future (ie. when the MARPOL VI amendments is in force) such energy efficiency index will be used as one of the monitoring tools to determine the incentives for

the vessel, with the requirements of certification of the ship's energy efficiency index. It is recommended propose new items for PSC MOU, which in this case would be for Singapore under the Tokyo MOU for regional voluntary checks on compliance. Such data could be shared among the countries and states.

- In order to have a better monitoring of the energy efficiency level for the Singapore Register Ships and ships participating in the 'Green Port Programme'; it is proposed to create an electronic platform for the recognized organization (RO) and the ship owner or operator to submit its energy efficiency index. This electronic system will enable direct linkage and reporting and analysis of the existing status of emission level, and also create a baseline for future comparison purposes.

7. CONCLUSION

UN being the top of the hierarchy at the international level has formed UNEP to govern international issues relating to climate change, and IMO which is responsible for governing issues relating to international shipping matters in terms of safety and environment. Overall we are witnessing the awareness for protection of the global environment being raised significantly around the world. Be it at international, regional or national levels, mechanisms, conventions, regulations and voluntary schemes have been introduced to reduce air pollution and the emissions of GHG from the shipping sector.

The amendment to MARPOL 73/78 by introduction of a new annex to address air pollution has been a significant effort to reduce ship-based air pollution. This year's MEPC adoption of EEDI and SEEMP marks another great effort from the maritime industry to not only look at air pollutants, but also the GHG emissions from ships. Remaining is the deliberation of EEOI and MBMs pending the evaluation of the Expert Groups evaluations on the various proposals submitted. Nevertheless, a common goal on the usage of the fund is reached (ie. to be collected through the MBMs) to assist the developing countries in technology for reduction of emissions from shipping and technical cooperation purposes.

Efforts to address ships' emissions through development of new innovations are also observed. Be it from modification to ship's infrastructure and design, to alternative fuels other than fossil fuels such as LNG, hydrogen, and nuclear power have been explored by the industry at great length. However, in order for ships to be able to make use of these technologies, or switching to alternative fuels, additional investments are required from the shipping companies. Hence, most shipping companies are waiting for the results of the feasibility study on the "supply and demand of low-sulphur fuels" which will be

carried out by IMO in 2018, prior to committing to the next step to their business strategy. On the contrary, some companies have seen introducing the improved ships designs and technologies on their new-build ships as a benefit to the “branding” for their company image, which can act as an enhancement to their business. Other than modification of ship’s structure and installation of technology, using of low-sulphur fuels such as distillates appears to be the most viable option for ships in short term, as it does not require any form of modification and does not disrupt the company’s business strategy.

Singapore riding on the wave of the “green port development” has also introduced policies to reduce air emissions from ships operating within its port and on Singapore registered ships. Other than ships, Singapore has also introduced fund to support innovations from local companies in development of technologies for reduction of air emission from ships. These policies are restricted to only within the port and its flagged ships. As recommended in the previous chapter, regional efforts should be studied to curb the ships’ emissions in the region in order to achieve better environmental results. A better enforcement mechanism should be established to keep track of the effects of the measures introduced. Being the top bunkering port in the world with a record sales volumes of US\$19 billion in revenue annually, Singapore should also make use of its influences to ‘upgrade’ the bunkering industry to cater for greater demand and supply of low-sulphur content distillates.

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Appendix 1 – Representative health and environmental effects of air pollutants

Table 8 - Representative health effects of air pollutants.

Air Pollutants	Possible Health Effects
Ozone	Lung functional impairment, increased airway responsiveness, increased susceptibility to respiratory infection, increased pulmonary inflammation, lung structure damage.
Carbon Monoxide (CO)	Cardiovascular effects, especially in those persons with heart conditions.
Nitrogen Oxides (NOx)	Lung irritation and low resistance to respiratory infections.
Particulate Matter (PM)	Premature mortality, aggravation of respiratory and cardiovascular disease, changes in lung function and increased respiratory symptoms, changes to lung tissues and structure, and altered respiratory defense mechanisms.
Volatile Organic	Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment.

Source: <http://www.californiaskywatch.com/>

Table 9 - Representative environmental effects of air pollutants.

Air Pollutants	Possible Environmental Effects
Ozone	Damage and reduction in resistance to diseases to crop and agriculture.
Carbon Monoxide (CO)	Similar health effects on animals as in human.
Nitrogen Oxides (NOx)	Acid rain, visibility degradation, particle formation, contribution towards ozone formation.
Particulate Matter (PM)	Visibility degradation and monument and building soiling.
Volatile Organic	Contribution towards ozone formation, odours and some direct effects on buildings and plants.

Source: <http://www.californiaskywatch.com/>

Appendix 2 – EU progress towards Kyoto targets in 2008

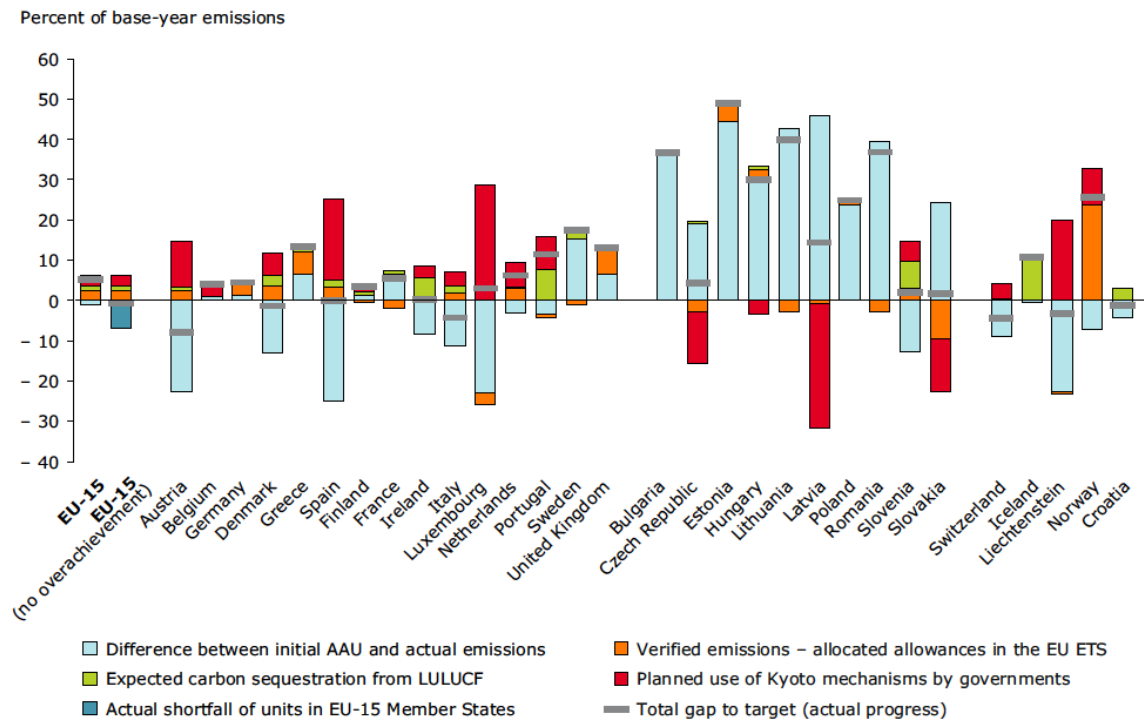


Figure 24 - EU current progress towards Kyoto targets in 2008.

Source: EEA, Report in tracking of progress towards Kyoto targets and 2020 targets in Europe, 2010.

Appendix 3 – Overview of existing and developing regulations

Table 10 - Overview of existing regulations implemented, or going to be implemented for reduction ship emissions.

IMO Regulations			EU Regulations			California (US) Regulations			Canada Regulations		
Timeline	Restriction	Coverage/ Status	Timeline	Restriction	Coverage/ Status	Timeline	Restriction	Coverage/ Status	Timeline	Restriction	Coverage/ Status
Technical Requirements			Technical Restrictions			Technical Restrictions					
1 Jan 2000	Engines built from Jan 2000 to comply with NOx Technical Code	Global/ In force	16 Aug 2006	No sale of >1.5% SOx MDO	EU ports/ In force				1 Oct 2007	No sale of >0.05% SOx MDO	In force

IMO Regulations			EU Regulations			California (US) Regulations			Canada Regulations		
13 Apr 2008	International Air Pollution Prevention Certificate	Global/ In force	1 Jan 2010	No sale of >0.1% SOx MGO	EU ports/ In force				1 Jun 2012	No sale of >0.0015% SOx MDO	In force
Restrictions on SOx contents (Global)			Restrictions on SOx contents (EU Ports)			Restrictions on SOx contents (California waters extending upto 24 NM from baseline)			Restrictions on emission of black smoke (Canada waters and within 1NM of land)		
19 May 2005	Max. 4.5% m/m SOx on bunker fuel	In force	Jul 2000	Max. 0.2% m/m SOx of MGO	In force	1 Jan 2007	Max. 1.0% SOx in MGO & 0.5% in MDO	In force	2007	Subject to density level determine on Smoke Chart	In force

IMO Regulations			EU Regulations			California (US) Regulations			Canada Regulations		
1 Jan 2012	Max. 3.5% m/m SOx on bunker fuel	Due for enforcement	11 Aug 2006	Max. 1.5% m/m SOx on bunker fuel (Scheduled passenger ships carrying more than 12)	In force	Jan 2012	Max. 0.1% SOx in MGO & MDO	In force			
1 Jan 2020	Max. 0.5% m/m SOx on bunker fuel	Under debate	1 Jan 2008	Max. 0.1% m/m SOx on MGO	In force						
			1 Jan 2010	Max. 0.1% m/m SOx on bunker fuel	At berths and inland waterways /						

IMO Regulations			EU Regulations			California (US) Regulations			Canada Regulations		
									In force		
Restrictions on SOx contents (SECA/ ECA)			Restrictions on SOx contents (SECA)								
19 May 2006	Max. 1.5% m/m SOx on bunker fuel	Baltic Sea/ In force	11 Aug 2006	Max. 1.5% m/m SOx on bunker fuel	Baltic Sea / In force						
22 Nov 2007	Max. 1.5% m/m SOx on bunker fuel	North Sea/ In force	11 Aug 2007	Max. 1.5% m/m SOx on bunker fuel	North Sea / In force						

IMO Regulations		EU Regulations	California (US) Regulations	Canada Regulations
1 Mar 2010	Max. 1.0% m/m SOx on bunker fuel	Baltic & North Seas/ Due to for enforceme nt		
1 Jan 2015	Max. 0.1% m/m SOx on bunker fuel	Baltic & North Seas/ Due to for enforceme nt		

Source: Summarized by author, master's dissertation, World Maritime University, Malmo, Sweden.